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FLUIDIZED-BED INCINERATION OF SELECTED CARBONACEOUS INDUSTRIAL WASTES

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FLUIDIZED-BED INCINERATION OF SELECTED CARBONACEOUS INDUSTRIAL WASTES

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~~A program was conducted on~~ the feasibility of fluidized-bed incineration for selected carbonaceous industrial wastes was evaluated. The two-phase program consisted of an initial phase in which wastes from the paint, plastics, rubber, and textile industries in Ohio were characterized, and a second phase in which various waste samples were obtained, analyzed, and experimentally incinerated in a 10 inch diameter fluidized-bed system. Results ~~of the program~~ indicate that sludges from solvent recovery operations in the paint industry, sludges from primary treatment of process wastes from plastic manufacturing, flotation sludges from primary treatment of synthetic rubber manufacture, and the waste from the viscose process of the textile industry can be incinerated in a fluidized-bed system without the production of noxious or toxic exhaust gases. The program also indicates that incineration of the various wastes significantly reduces their potential impact on stream pollution. It is recommended that a demonstration plant be constructed and operated at a site close to the source of several types of industrial wastes. (Lowry-Texas)

*Industrial wastes, *Incineration, *Chemical wastes, Flotation, Sludge, Water pollution control, Textiles, Suspended solids, Hydrogen ion concentration, Waste water treatment

*Carbonaceous wastes, *Fluidized-bed operation

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FLUIDIZED-BED INCINERATION OF SELECTED CARBONACEOUS INDUSTRIAL WASTES

by

Battelle Laboratories
505 King Avenue
Columbus, Ohio 43201

for the

STATE OF OHIO DEPARTMENT OF NATURAL RESOURCES
and
THE OFFICE OF RESEARCH AND MONITORING,
ENVIRONMENTAL PROTECTION AGENCY

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ABSTRACT

This report describes a program that was conducted on the feasibility of fluidized-bed incineration for selected carbonaceous industrial wastes. The program consisted of an initial phase in which wastes from the paint, plastics, rubber, and textile industries in Ohio were characterized. In the second phase, samples of various wastes were obtained and analyzed, and based on their characteristics, selected wastes were experimentally incinerated in a 10-inch-diameter fluidized-bed system.

Results of the program indicate that sludges from solvent recovery operations in the paint industry, sludges from primary treatment of process wastes from plastic manufacturing, flotation sludges from primary treatment of synthetic rubber manufacture, and the waste from the viscose process of the textile industry can be incinerated in a fluidized-bed system without the production of noxious or toxic exhaust gases. The program also indicates that incineration of the various wastes significantly reduces their potential impact on stream pollution. It is recommended that a demonstration plant be constructed and operated at a site close to the source of several types of industrial wastes.

This report was submitted by Battelle, Columbus Laboratories, in fulfillment of Grant Number 12120 FYF by the United States Environmental Protection Agency, to the Department of Natural Resources of the State of Ohio.

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SECTION I

CONCLUSIONS

This study has indicated that certain waste materials generated by the paint, plastic, rubber, and textile industries can be successfully disposed of by incineration in a fluidized-bed system. Based on a survey of these industries in Ohio and on the results of experimental incineration studies, the following conclusions were drawn.

(1) In the paint industry, an incineration process would be particularly effective for disposal of solvent recovery sludges and other aqueous wastes such as latex wash-out water and reaction waters from resin production. These wastes can create difficulties by disposal in landfills or municipal sewers. It was experimentally demonstrated that all of these materials can be incinerated concurrently in a fluidized-bed system. No fuel was required due to the high heating value of the solvent-bearing sludges, and essentially no noxious or toxic materials were present in either the exhaust gases, the gas scrubber effluent, or the residue remaining after incineration. A full-scale incinerator required for a typical plant was estimated to be about 6 feet in diameter and cost about $200,000. Operating costs were estimated at $140 per day or 1.1¢ per pound of waste.

(2) Primary treatment sludges from the plastic industry can be disposed of by fluidized-bed incineration using supplemental fuel addition. One source of fuel might be the large quantities of solid plastic waste generated by this industry. The experimental studies indicate that essentially no toxic or noxious materials are produced during incineration of styrene or PVC wastes other than hydrogen chloride which is removed in gas scrubbing effluent. An incineration facility capable of handling the primary treatment sludge from a typical plant was estimated to be 12 feet in diameter and to cost about $350,000. Operating costs, however, were estimated to be less than 0.2¢ per pound of sludge containing an average of 10 percent solids. Although these wastes currently are being disposed of by landfill and apparently do not represent a serious pollutional danger, it was concluded that incineration might show an economic incentive compared to the cost of disposal by landfill.

(3) Sludges from the rubber industry can be incinerated in a manner similar to that used for plastic wastes. Although very little definite information was obtained, the major sludges that appear amenable to incineration are those from primary treatment of process waste water and those from rubber reclaiming operations. Experimental work with a flotation sludge from a large rubber company indicates excellent incinerator

operation and no generation of noxious components. On the basis of 10,000,000 pounds of sludge annually, it was estimated that a 7.5 foot diameter incinerator would be required. Capital costs were estimated to be $250,000 and operating costs of 0.4¢ per pound of sludge incinerated.

(4) The use of incineration for disposal of textile wastes does not appear promising. The size of the textile industry in Ohio has decreased greatly in the last 20 years and probably generates a very low pollutional effect compared to the other industries studied. The only textile waste investigated experimentally in this program was from viscose rayon production; incinerator operation in this case was poor due to the presence of low melting point inorganic waste materials. Extensive additional study would be needed to perfect an incinerator for this waste. Although other wastes are generated by the textile industry, these are generally extremely dilute and not amenable to incineration.

SECTION II

RECOMMENDATIONS

This program involved the characterization of wastes from the paint, plastics, rubber, and textiles industries in Ohio as well as experimental fluidized-bed incineration of selected wastes from these industries. The scope of the program was to determine the technical and economic feasibility of fluidized-bed incineration of these wastes. Based on the results obtained in the program, it is recommended that a demonstration plant be constructed and operated at a convenient site for the disposal of all types of industrial wastes of interest in this study.

There is a possibility of blending wastes from several industries prior to incineration. This would allow the utilization of the heating value of some wastes to incinerate other, more dilute wastes. Several types of wastes not included in this program possibly could be added. Other waste materials which might be considered are (1) sewage sludges, (2) lake or river bottom dredging, and (3) petrochemical sludges.

Transportation of the wastes to a centrally located incinerator as well as the necessary storage tank and blending facilities would be needed. A brief study of these factors should be included in the recommended program. The possibility of heat recovery from the incineration system also should be considered.

All of the above-mentioned factors, particularly the blending of high heating value wastes with dilute waste and heat recovery, could enhance the economics of the system considerably. If the facility were located in a large city, carbonaceous wastes currently being discharged into the municipal sewers could be incinerated. This would decrease the loading on the sewage treatment system. In this case, the incinerator would be constructed near the sewage treatment plant so that sewage effluent could be used as the scrubbing medium. The scrubber effluent would be returned to the sewage plant for treatment. A long-range study (2-3 years) of the effects of incinerating some of the industrial carbonaceous wastes now being discharged into a municipal sewage system on the subsequent operations of that system is recommended.

SECTION III

INTRODUCTION

Battelle's Columbus Laboratories was instrumental in the development of a fluidized-bed incinerator system for the disposal of waste liquors from the neutral sulfite semichemical (NSSC) pulping of wood for the production of corrugating medium. Since the initial development of this system a number of commercial installations utilizing this technique have been constructed and are in operation. In addition, studies have been made of the use of fluidized-bed systems for the disposal of wastes from other segments of the pulp and paper industry, as well as from petrochemical and petroleum industries. Commercial-scale systems also have been constructed for the disposal of wastes from these industries.

The disposal of carbonaceous liquid wastes by fluidized-bed incineration usually consists of the following steps:

(1) Concentrating the wastes in multiple effect evaporators to a level where the fuel value of the concentrate is sufficient to evaporate the remaining water and raise the temperature of the waste to the desired incineration temperature.

(2) Introducing the concentrated waste into the top of the incinerator as a fine spray. However, viscose wastes and wastes containing large amounts of volatile solvents were introduced directly into the bed of fluidized solids.

(3) Contacting the droplets with a bed of fluidized solids held at a temperature sufficiently high to burn all of the carbonaceous matter.

(4) Recovering the residual inorganics and noncombustible portion of the waste either from the bed of fluidized solids as an agglomerated product or from the exhaust gases as a finely divided dust.

The operating conditions in a fluidized-bed system can be readily controlled within very narrow ranges, a factor which makes possible the incineration of carbonaceous wastes while minimizing the generation of noxious fumes. In addition, these systems efficiently utilize the fuel value of the wastes. They can be operated at temperatures which will effect the agglomeration and the retention of many materials in the bed of fluidized solids, thus minimizing the entrainment of particulate matter in the exhaust gases, if desired.

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Because of the effectiveness of fluidized-bed incineration systems in the disposal of pulping and papermaking wastes, as well as other carbonaceous wastes, it was believed that such systems also might be applied advantageously to the abatement of water pollution by carbonaceous waste from other industries.

Another factor in the recommendation of this program was pointed out in a BCL study on the state of the art of industrial waste treatment. The result of that study pointed up the need for more effective means of industrial treatment to eliminate or minimize the discharge of pollutants into streams and sewers.

In view of these factors, Battelle proposed that the Ohio Department of Natural Resources request a research grant from the Federal Water Quality Administration to evaluate fluidized-bed incineration of wastes from four Ohio industries (textile, plastics, rubber, and paint).

This program was outlined in Battelle's proposal to the State of Ohio, Department of Natural Resources of January 16, 1970. It was proposed that the initial phase of the program consist of the following four specific tasks:

(1) The acquisition and assessment of data on the characteristics of major waste streams from the selected industries and their potential for disposal by incineration

(2) An experimental evaluation of the fluidized-bed incineration of wastes selected on the basis of their probable amenability to treatment, the severity of the problem of their disposal, and their pollutional potential

(3) A preliminary evaluation of the technical and economic feasibility of the proposed technique and the preparation of recommendations for its continual development on a pilot scale

(4) The preparation of a formal report covering the results obtained in 1 through 3.

This proposal was accepted by the Department of Natural Resources and work was begun in July, 1970. This report is concerned with the results of that program.

SECTION IV

BACKGROUND INFORMATION

Description of Industries

Paint

The production of paints in the State of Ohio involves many large scale plants and a wide variety of operations. The paint industry is represented by plants producing both consumer paints and industrial paints such as automotive enamels and lacquers.

In the manufacture of paints, wastes are encountered, primarily, in the cleaning and washing of reactors, blenders, tanks, etc., and in general plant clean-up operations. Secondary waste sources are rejected or otherwise unacceptable batches of paint and returned goods.

The type of wastes produced in the paint industry can be classified in two categories: those resulting from oil-base paint production which are largely organic, and those resulting from water-based paint manufacture which are generally dilute aqueous solutions containing organic and inorganic components. Waste loads are apparently distributed about equally between these two types.

In the manufacture of oil-base paints, organic solvents are used for most cleaning and washing operations. For economic reasons, wash-out solvents generally are collected and reused a number of times before they are disposed of. Many plants practice a recovery operation in which distillation of dirty solvent is used to recover about 80 percent of the feed as clean solvent for reuse within the plant. Some plants truck the dirty solvents to an independent salvage firm which also uses distillation for recovery of clean solvent. The locality of a particular plant apparently has much to do with whether or not a company uses independent or in-plant recovery. In either case, the distillation operations end up with a still bottoms or sludge which ultimately must be disposed of either by the paint company or by the independent operator.

Sludges or bottoms resulting from dirty solvent recovery have in the past been disposed of at various landfill sites within Ohio. This practice is becoming more and more difficult due to current restrictions and some plants are now forced to use out-of-state landfill sites. In at least one instance, the bottoms are being successfully incinerated outside of the State of Ohio. The use of landfill also is employed for disposal of returned goods and bad batches of paint.

The production of water-base paints on the other hand results in entirely different waste characteristics and thus disposal practices. Wash-out and cleaning operations generally use large volumes of water which are then discarded after a single use. The wastes are dilute but still contain significant organic loadings from resins and binders, and contain colored inorganic pigments. Disposal of these wastes is generally accomplished through the use of municipal sewers where the waste is greatly diluted with plant cooling water.

In addition to the general wash-out and plant cleaning waste waters, there are several other operations involved in paint manufacture in which wastes are produced. These, basically, arise during the manufacture of resins and binders which is sometimes carried out in the same plant used for mixing of paints or is conducted at a separation location. During production of certain types of resins such as the phenolic types, a significant quantity of water-of-reaction results. This particular waste contains high organic loadings and is very offensive. Various methods are being used for disposal of resin reaction waste waters, including incineration and trucking to municipal sewage plants. In the production of resins, general wash-out and cleaning wastes also are produced. These wastes are highly basic since caustic is used for most cleaning operations.

Plastics

The basic processing step involved in plastics production is polymerization of monomer to polymer. The technology involved in polymerization has been known for over 20 years and very little change has occurred during this time. Generally, the polymerization step is carried out by one or a combination of four processes, depending on the type of plastic or resin being manufactured. These are

(1) Suspension polymerization
(2) Solution polymerization
(3) Batch condensation process
(4) Emulsion polymerization.

From a waste generation standpoint, by far the most important of these processes is the suspension polymerization process. In this process, the monomer is dispersed as small droplets in a suspending medium consisting of water and small quantities of catalysts and suspending agents. Significant waste waters are generated after centrifugation or filtration of the mixture to remove the polymerized product. Wastes also are generated during washing of the product and in cleanout operations.

Typical examples of the type of plastics produced in Ohio by suspension polymerization are the vinyl and polystyrene resins.

The production of vinyl resins, for example, is currently estimated to be over 2.5 billion lb/year and ranks second only to polyethylene in total resin production capacity. About 85 percent of the vinyl resins are produced by the suspension polymerization process. The waste water from vinyl resin manufacture contains: (1) suspending agents, (2) surface active agents, (3) catalysts or initiators, (4) small amounts of unreacted monomer, and (5) fine particles of the polymer product. Generally the waste water is high in organic loading--as much as 1,000 ppm BOD and 100 ppm suspended solids. Most of the resin manufacturers employ only primary treatment to remove suspended solids. Approximately half of the plants also use municipal sewers for disposal of the waste waters after a primary treatment step.

The production of polystyrene resins and copolymers is almost as great as vinyl resins and a growth pattern similar to that from vinyl resins is expected. Styrene resins are also produced by a suspension polymerization process which is usually preceded by a bulk prepolymerization step. The significant water wastes produced are reaction water and wash water resulting from the centrifugation, filtration, and washing of polymerized product.

The waste waters from polystyrene manufacture typically have a low concentration of pollutants because of the small quantities of additives used in the process. The additives can be of a wide variety including catalysts of the peroxide type, suspending agents which are organic, and various inorganic materials such as calcium carbonate, calcium phosphate, talc, clays, and silicates. Many of the large styrene producing plants employ a primary treatment of the waste waters before disposal either to a stream or sewer.

Rubber

Rubber manufacturing in the State of Ohio and the wastes generated by this industry may be divided into three general classes: (1) natural rubber including all rubberlike materials produced from the plant sap; (2) synthetic rubber made by copolymerization of several chemicals including butadiene, styrene, isoprene, chloroprene, etc.; and (3) reclaimed rubber. The latter two categories make up the major waste contribution from the rubber industry.

In the manufacture of synthetic rubber, butadiene is mixed with some other mononer such as styrene plus a catalyst to produce synthetic latex. Coagulation of the latex either with an acid salt solution or with alum follows, after which the latex is washed, dried, and baled. Wastes from synthetic rubber manufacture typically consist of coagulated rubber crumbs, plus acid and salt solutions and occasionally batches of materials which will not polymerize properly. The wastes generally have a high BOD, and bad taste, and odor. Most large plants currently employ some type of treatment for rubber manufacturing wastes and usually generate large quantities of sludge which are disposed of by landfill.

In reclaiming used rubber, the processes basically consist of shredding and grinding the old rubber after which any bits of metal and most of the fabrics are removed by screening and separation processes. The ground rubber and fabric is then subjected to a caustic treatment at high temperatures for several hours which destroys the fabric and frees the rubber. The recovered rubber is then washed, dried, milled, strained, and refined for reuse. The wastes from rubber reclaiming basically consist of the scraps, fabric, and metal pieces removed from the rubber and any sludges produced from the treatment of spent caustic solutions.

Textile

The textile industry consists of two distinct segments: (1) natural fibers, and (2) synthetic fibers. The principal sources of natural fiber considered are cotton and wool. In the finishing of the natural fibers, the processing may be simply described as follows:

(1) Sizing of raw fiber with slashing starch to aid in the weaving

(2) Desizing to allow wet processing

(3) Keiring or scouring to remove natural impurities

(4) Bleaching to whiten the fibers.

In the production of synthetic fibers the process is less involved since the sizing and desizing steps are eliminated.

The trend in the textile industry is toward the development of methods which eliminate the need for waste treatment by process chemical changes, segregation, equalization, and recovery. However, in considering pollution abatement, it should be realized that the bulk of the pollution is contributed by only two wastes in cotton mills (desizing and scouring or kiering) and in woolen mills (scouring and washing after fulling). The segregation and treatment of these specific waste streams by concentration and incineration techniques has been recommended as a major step in alleviating stream pollution.

The textile industry in the State of Ohio is quite small. There are, however, several small plants involved in yarn dyeing, cording and combing of scrap cloth, etc. The waste from the dyeing operation is very dilute and is normally discharged to city sewerage systems. Very little liquid waste is generated in the cording and combing operation. The production of synthetic fibers is the major segment of the industry now in existence in Ohio. However, the waste load from this industry does not appear to be significant at this time except for isolated plants.

The basis for this background information was taken from the articles listed in the bibliography section of this report, as well as from information collected during the visits with various plant operating personnel.

Characteristics of Wastes

Paint Production

The primary wastes generated from paint production in Ohio can be grouped in the following three categories:

(1) Waste organic solvents which contain varying amounts of resins, binders, and pigments. This cateogry would include all wash-out and cleaning solvents the sludges from these solvents if recovery is practiced, and other minor items such as reject batches of paint and "returned goods"

(2) Aqueous waste waters which contain varying amounts of resins, binders, pigments, and caustic. These wastes are generated primarily during wash-out and cleaning of equipment used for water-base paint manufacture

(3) Water of reaction from production of certain organic resins used in paint formulations.

The only other wastes generated in paint manufacture are solid wastes such as waste paper, fiber board, plastic wrappings, etc. Although these wastes may represent a considerable volume and cost to the plant for disposal, they are relatively insignificant with respect to water pollution and were not considered further in this program.

The wastes generated in the above three categories differ widely with regard to quantities, composition, and current disposition. On the basis of plant visits and discussions conducted during this program, a cross section of the paint industry in Ohio was developed.

The type of wastes generated, their quantities, and current disposition at the plants visited during this survey are listed in Table 1. These data indicate that combined effluents and reaction waters from resin production represent the largest quantities of waste for disposal. These wastes are, in most cases, handled by municipal sewage systems but in one specific plant the wastes were incinerated. Solvent bearing wastes can represent up to about 1,000 gpd for a typical plant and are currently being disposed of by landfill in most cases. In addition, incineration or sewage plant disposal of solvent wastes is practiced by specific plants in Ohio.

TABLE 1. TYPES, QUANTITIES, AND DISPOSITION OF PAINT WASTES FROM TYPICAL PLANTS IN OHIO

Type of Waste	Generated Annually	Current Disposition
Combined Effluent	108,000,000 gal	Municipal sewer
Reaction Water-Resin Manufacture	200,000 gal	Trucked to sewage plant
Solvent Recovery Sludge	120,000 gal	Landfill
Latex Wash-Out Water	200,000 gal	Landfill
Combined Effluent-Resin Manufacture	390,000 gal	Incinerated
Solvent Recovery Sludge	250,000 gal	Incinerated
Solvent Recovery Sludge	120,000 gal	Landfill
Waste Solvent	30,000 gal	Landfill
Solvent Recovery Sludge	39,000 gal	Sewage Plant

Note: For a national distribution of paint manufacturing plants, see Figure A-1, page 82.

The composition of paint wastes also varies widely depending on the category or type of waste considered. As an example of the many ingredients used in paint formulations, a typical list of ingredients for latex and oil-base paints is shown in Tables 2 and 3. Although quantities are not given, it is evident that many toxic or highly pollutional substances are used in the formulations. These include phosphates, mercury, chromium, cyanides, phenols, asbestos, lead, barium, cobalt, and chlorinated organics. It is valid to assume that a certain percentage of these pollutants will ultimately end up in the waste materials from these plants.

As part of the initial phase of this program specific waste materials generated in the paint industry were obtained and analyzed. The results of analyses of paint waste samples obtained during the program are shown in Tables 4, 5, and 6. The samples are grouped in the three categories described above. The data shown in Table 4 illustrate the high values for total solids, COD, and heating value typical of solvent bearing wastes. These data also point out that ash content is generally less than 10 percent; thus, waste volumes could be reduced over 90 percent by incineration.

The analyses of aqueous waste waters (Tables 5 and 6) indicate a total solids content generally between 2 and 5 percent except for combined effluents which are very dilute due to mixing with large quantities of cooling water. The results show that the solids are basically organic and exhibit a high COD. The most objectionable waste appears to be reaction water from the manufacture of resins.

Plastic Production

The wastes generated by the plastic industries in Ohio are of two general types:

(1) Waste sludges produced during primary treatment of combined plant effluents, process waters, etc.

(2) Solid materials which are largely waste polymers, plastic scrap, etc., combined with other inorganic materials.

In certain instances, some plants also generate waste solvents and reaction waters from resin manufacture, which are similar to those generated in the paint industry. The relative quantities of the wastes generated and current disposition for specific plastic manufacturing plants visited are shown in Table 7. As shown, the production of solid waste materials (polymers, sanding dust, plastic scrap) results in the largest quantities of material for disposal. The combined output of only two plants amounts to approximately 35,000,000 pounds annually. These materials currently are being sent to a landfill.

TABLE 2. INGREDIENTS IN LATEX PAINTS

Liquids		
	Water	
	Latex - (acrylic or vinyl acrylic resins)	
	Glycols	
	Coalescing agents:	
	pine oil	
	tributyl phosphate	
	aromatic glycol ether	
	odorless mineral spirits	
	nonbiodegradable surfactants	
	potassium tripolyphosphate	
	emulsifiable lecithin	
	cellulosic compounds	
	mercury compounds	
Pigments		
	Titanium dioxide	Major items
	Clay	
	Calcium carbonate	
	Silica	
	Oxides of iron	Minor items
	Chromium green oxide	
	Hansa yellow	
	Carbon black	
	Umbers	
	Asbestos fibre	
	Phthalocyanine blue and green	

TABLE 3. INGREDIENTS IN OIL-BASE PAINTS

Liquid

- Oils (vegetable or marine)
- Alkyds (phthalic glycerides or pentaerythritides)
- Varnishes:
  - phenolic resins
  - petroleum resins
  - rosin esters
  - epoxy resins
  - gilsonite
  - asphaltum
- Solvent:
  - petroleum solvents
  - aromatic or alyphatic hydrocarbons
  - alcohol (butyl or isopropyl)
  - ethylene glycol (monoethyl ether)
  - ethylene glycol (monoethyl acetate)
  - methylisobutyl ketone
  - methylethyl ketone

Pigment

- Titanium dioxide
- Red lead
- Zinc oxide
- Basic lead silica chromate
- Lead chromates
- Iron blues
- Thalocyanine blue and green
- Iron oxides
- Organic red pigments
- Aluminum flakes
- Asbestos fibre
- Chromium green oxide
- Carbon black
- Black iron oxide
- Silicates (magnesium and aluminum)
- Calcium carbonate
- Silica
- Lead molybdate
- Strontium chromate
- Organic orange toner
- Organic yellow toner (hansa)
- Zinc sulfide
- Barium sulfate lithopone

Chemicals

- Chlorinated paraffin
- Organic mercury compounds (solvent soluble)
- Silicone fluid
- Driers:
  - Organic compounds of:
    - lead
    - manganese
    - cobalt
    - zinc
    - calcium
    - zirconium

TABLE 4. ANALYSES OF SOLVENT-BEARING WASTES FROM THE PAINT INDUSTRY

Sample Number: / Description:	(4) Solvent Recovery Sludge	(6) Varnish Wash-out Solvent	(7) Solvent Recovery Sludge	(8) Solvent Recovery Sludge	(13) Solvent Recovery Sludge	(15) Varnish Wash-out Sludge	(16) Returned Goods
Specific gravity	0.926	0.857	0.940	1.000	0.956	0.890	1.411
pH	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Total solids, mg/l	114,000	4,000	258,000	377,000	495,000	83,000	1,000,000
Ash content, mg/l	36,500	536	28,400	68,000	7,400	22,400	579,000
Total carbon, mg/l	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Organic carbon, mg/l	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Chemical oxygen demand, mg/l	89,000	6,560	364,000	636,000	1,100,000	126,000	1,890,000
Total nitrogen, mg/l	100	0	5,950	1,620	4,150	670	3,000
Organic nitrogen, mg/l	0	0	5,900	1,600	4,100	600	2,900
Ammonical Nitrogen, mg/l	0	0	0	0	0	0	0
Nitrate- nitrite, nitrogen, mg/l	100	0	35	25	30	60	25
Total phosphorous, mg/l	1,100	0	600	300	60	90	350
Heating value, Btu/lb	15,300	15,300	15,900	17,250	15,850	17,635	13,770

N.A. = not analyzed.

TABLE 5. ANALYSES OF GENERAL PROCESS WASTES FROM THE PAINT INDUSTRY

Sample Number: / Description:	(2) Combined Effluent	(14) Latex Wash-Out
Specific gravity, g/ml	0.996	1.015
pH	11.6	8.9
Total Solids, mg/l	4,000	40,000
Ash Content, mg/l	2,600	27,000
Total Carbon, mg/l	680	8,900
Organic Carbon, mg/l	400	6,200
Chemical Oyxgen Demand, mg/l	2,900	190,000
Total Nitrogen, mg/l	200	250
Organic Nitrogen, mg/l	200	200
Ammonical Nitrogen, mg/l	0	0
Nitrate- Nitrite Nitrogen, mg/l	0	60
Total Phosphorus, mg/l	100	60
Heating Value, Btu/lb	8	160

TABLE 6. ANALYSES OF PROCESS WATERS FROM RESIN PRODUCTION IN THE PAINT INDUSTRY

Sample Number :	(1)	(3)	(5)
Description:	Combined Effluent	Reaction Water and Caustic Wash-Out	Reaction Water
Specific Gravity, g/ml	1,000	1.007	1.027
pH	3.8	11.7	3.7
Total Solids, mg/l	26,000	23,000	49,000
Ash Content, mg/l	1,700	10,000	3,400
Total Carbon, mg/l	33,000	23,000	180,000
Organic Carbon, mg/l	15,000	17,000	160,000
Chemical Oxygen Demand, mg/l	88,000	66,000	650,000
Total Nitrogen, mg/l	200	300	400
Organic Nitrogen, mg/l	100	200	300
Ammoniacal Nitrogen, mg/l	0	0	0
Nitrate - Nitrite Nitrogen, mg/l	100	100	100
Total Phosphorus, mg/l	100	100	0
Heating Value, Btu/lb	250	125	465

TABLE 7. TYPES, QUANTITIES, AND DISPOSITION OF PLASTIC WASTES FROM TYPICAL PLANTS IN OHIO

Type of Waste	Quantity Generated Annually	Current Disposition
Waste PVC Granules	800,000 lb	Landfill
Primary Treatment Sludge	6,000,000 lb	Landfill
Waste Polymers	16,000,000 lb	Landfill
Sanding Dust	14,400,000 lb	Landfill
Scrap Plastics	3,800,000 lb	Landfill
Reaction Water	750,000 gal	Landfill
Waste Solvents	120,000 gal	Landfill
Waste Solvents	25,000 gal	Landfill
Primary Treatment Sludge	3,500,000 lb	Landfill

Note: For a national distribution of plastic manufacturing plants, see Figure A-2, page 83.

The production of large quantities of sludge from primary treatment of combined plant effluents, process waters, etc., also represent a significant waste problem in the plastic industry. The plants visited in Ohio all employ or are constructing some type of treatment process for combined plant effluents. The sludges produced are being disposed of by landfill at sites either owned by the companies themselves or at independent locations. In the two plants listed approximately 10,000,000 pounds of primary treatment sludge are produced annually.

Disposal of waste solvents and reaction water represents only a minor problem for the plastic industry. In one case, reaction water is being successfully fed to boilers and incinerated.

The analyses of typical plastic wastes samples obtained during the study are shown in Tables 8 and 9. Generally, the wastes showing a high solids content also exhibited a low ash content and high heating value. This is indicative of the high organic content of the samples. An exception is Sample No. 19 which is a sludge from the demineralization of influent water and contains primarily calcium carbonate.

Rubber Production

Typical data on wastes generated by the rubber manufacturing plants visited in Ohio are shown in Tables 10, 11, 12 and 13. There are several types of waste produced depending on which segment of the industry is involved. In the manufacture of synthetic rubber, for example, waste sludges are produced from the primary treatment of process waste waters. These sludges contain rubber crumbs, fatty acids, and other processing chemicals. No information was readily obtainable on the quantities of sludge produced but the amount is believed to be significant. In one plant the quantity of sludge produced was estimated at 10,000,000 pounds annually. The sludges are being disposed of by landfill.

In plants producing specialty rubber products (hoses, gaskets, gloves, etc.) the major waste problem is the scraps, trimmings, flash, and other solid materials resulting from the various mechanical operations in the preparation of the products. These materials amount to a significant quantity per year (3 to 6 million pounds) and are being disposed of by landfill. Apparently, some plants have investigated incineration as a means for disposal but have abandoned the method for various reasons. The high ash content of these solid rubber wastes (about 30 percent) indicates that only a 70 percent reduction of landfilling usage would be achieved by incineration.

Another segment of the rubber industry in which significant wastes are produced involve those plants which are primarily engaged in reclaiming rubber from old tires. In the grinding, screening, and separation of the materials in tires, significant quantities of nylon, rayon, and rubber dust and scraps are produced. These materials can amount to approximately

TABLE 8. ANALYSES OF PROCESS WASTE WATERS AND SLUDGES FROM THE PLASTIC INDUSTRY

Sample Number : Description :	(9) Primary Treatment Sludge	(12) Reaction Water	(17) PVC Process Waste	(18) PVC Primary Treatment Sludge	(19) Influent Treatment Sludge
Specific Gravity	N.A.	1.001	0.983	0.994	1.077
pH	N.A.	7.6	N.A.	9.8	9.3
Total Solids, mg/l	564,000	4,000	108,000	3,000	135,000
Ash Content, mg/l	45,000	0	75	900	104,000
Total Carbon, mg/l	N.A.	42,000	N.A.	620	7,000
Organic Carbon, mg/l	N.A.	42,000	N.A.	500	1,100
Chemical Oxygen demand, mg/l	590,000	N.A.	120,000	250,000	40,000
Total Nitrogen, mg/l	6,300	540	425	15	210
Organic Nitrogen, mg/l	6,300	500	400	0	200
Ammoniacal Nitrogen, mg/l	0	0	0	0	0
Nitrate-Nitrite Nitrogen, mg/l	35	40	25	15	10
Total Phosphorus, mg/l	600	60	30	160	150
Heating Value, Btu/lb	8,300	N.A.	950	17	0

N.A. = Not analyzed.

TABLE 9. ANALYSES OF SOLID WASTES FROM THE MANUFACTURE OF PLASTICS

Sample Number: / Description:	(10) Shredded Plastic Scrap	(11) Plastic Sanding Dust	(20) Oversize PVC Waste
Moisture, %	5.5	63.5	3.0
Ash Content, %	1.9	0.7	0
COD, ppm	1,300,000	530,000	N.A.
Total Nitrogen, ppm	41,540	2,350	310
Organic Nitrogen, ppm	41,500	2,300	300
Ammoniacal Nitrogen, ppm	0	0	0
Nitrate- Nitrite Nitrogen, ppm	40	50	12
Total Phosphorus, ppm	170	140	20
Heating Value, Btu/lb	8,300	3,400	8770

N.A. = Not analyzed.

TABLE 10. ANALYSES OF SLUDGES FROM PRIMARY TREATMENT OPERATIONS IN THE RUBBER INDUSTRY

Sample Number:	(22)	(23)	(25)	(32)
Description:	Primary Treatment Sludge	Rubber Crumbs and Floaters	Primary Treatment Sludge	Flotation Product Sludge
Specific Gravity	1.016	0.992	N.A.	N.A.
pH	7.5	3.8	N.A.	N.A.
Total Solids, mg/l	44,000	110,000	500,000	154,000
Ash Content, mg/l	27,300	16,500	75,000	88,000
Total Carbon, mg/l	N.A.	N.A.	N.A.	N.A.
Organic Carbon, mg/l	N.A.	N.A.	N.A.	N.A.
COD, mg/l	21,000	182,000	540,000	122,000
Total Nitrogen, mg/l	920	210	N.A.	N.A.
Organic Nitrogen, mg/l	900	200	N.A.	N.A.
Ammoniacal Nitrogen, mg/l	0	0	N.A.	N.A.
Nitrate -Nitrite Nitrogen, mg/l	20	10	N.A.	N.A.
Total Phosphorus, mg/l	400	10	N.A.	N.A.
Heating Value, Btu/lb	104	1,530	4,150	2,300

N.A. = Not analyzed.

TABLE 11. ANALYSES OF SOLID WASTE FROM THE RUBBER INDUSTRY

Sample Number and Description	(24) Sanding	(26) Rubber Scrap, Trimmings, and Flash
Bulk Density, g/cc	0.35	0.45
Total Solids, %	41	100
Ash Content, %	7	30.5
COD, ppm	510,000	Na
Heating Value, Btu/lb	4,500	Na

TABLE 12. ANALYSES OF WASTES FROM RUBBER RECLAIMING OPERATIONS

Sample Number and Description	(30) Combined Effluent	(31) Digester Sludge
Specific Gravity	0.997	1.007
pH	5.0	4.7
Total Solids, mg/l	10,000	25,000
Ash Content, mg/l	1,700	3,900
COD, mg/l	24,000	54,000
Heating Value, Btu/lb	100	245

TABLE 13. SOURCES, QUANTITIES, AND DISPOSITION OF RUBBER WASTES FROM TYPICAL PLANTS IN OHIO

Type of Waste	Annual Waste Generated	Present Disposition
Rubber crumbs, fatty acids, and chemicals	Unknown	Sludge to landfill, effluent to sewer
Rubber scraps, trimmings, flash, etc.	2,880,000 lb	Landfill
Rubber scraps	6,000,000 lb	Landfill
Rubber, nylon, and rayon scraps from reclaiming operation	1,630,000 lb	Landfill
Sludge from reclaiming processes	1,000,000 lb	Landfill
Sludge from reclaiming processes	Unknown	Lagoon
Sludge from primary treatment	10,000,000 lb	Landfill
Sludge from primary treatment	Unknown	Landfill

Note: For a national distribution of synthetic rubber manufacturing plants, see Figure A-3, page 84.

1.5 million pounds annually for a typical plant. In addition, an equivalent amount of waste sludge is produced during the cooking of the rubber in organic oils. These sludges generally have a high solids content and high COD.

The sludges and other wastes from rubber reclaiming are currently being disposed of by landfill.

Textile Production

The quantity of textiles produced in Ohio is very small compared to other sections of the country and very little information was obtained on the characteristics of waste from this industry. Of the two plants which were surveyed, one was involved in the manufacture of wool yarn; the other produced viscose. The analyses of wastes produced in these two plants are shown in Table 14. The composition of dye wastes from the dyeing of

TABLE 14. ANALYSES OF WASTES FROM TEXTILE INDUSTRY

Sample Number and Description	(27) Dye Waste	(28) Dye Waste	(29) Viscose Waste
Specific gravity	0.991	0.992	1.120
pH	6.4	6.5	Na
Total Solids, mg/l	198	3,075	230,000
Ash Content, mg/l	87	1,048	90,000
COD, mg/l	355	751	121,000
Heating Value, Btu/lb	1	8	1,000

wool show that this material is very dilute and has low pollutional value. These waste waters currently are being disposed of in municipal sewers. The viscose waste, on the other hand, has significant total solids content and high COD. The solids are largely organic and have a high heating value. Viscose wastes currently are being disposed of by landfill.

Selection of Samples for Experimental Studies

Prior to undertaking the experimental studies, the various waste samples obtained from the four industries described were evaluated to determine which were most amenable to fluidized-bed incineration. The samples were selected, primarily, on the basis of (1) solids content, (2) heating value, (3) pollutional constitutents, and (4) quantity produced. For presentation in this report, each industry will be discussed separately.

Paint

One of the wastes selected from the paint industry was the bottoms or sludge remaining after distillation of the solvents that are used for cleaning equipment. Two solvent-bearing sludges were selected for experimental incineration in the fluidized bed unit. One of the sludges was from a solvent recovery (distillation) operation of a large paint manufacturing plant. It was felt that this sludge was representative of the paint manufacturing plants that operate their own recovery system. This waste contained about 52 percent total solids and 0.8 percent ash. The heating value of the waste, as received, was 16,130 Btu/lb.

The second sludge or still bottoms selected for fluidized-bed incineration experiments was from a firm that recovers solvent from several paint plants and does not manufacture paint. This sludge contained about 37.7 percent solids and 6.8 percent ash. The heating value of this material, as received, was 15,910 Btu/lb.

A third waste selected for study was the washout water from latex paint production, which represented a typical aqueous waste generated by the paint industry. The total solids content of this waste was only 7 percent, and its heating value was 3,920 Btu/lb. This waste was selected for experimentation primarily on the basis of its high pollutional potential.

One additional waste from the paint industry was selected for experimentation because it was felt that it could be used as cooling water during incineration of the high heating value still bottoms. This waste was the very dilute (49,000 mg solids/liter) water of reaction (decanter water) collected during resin production.

Plastics

Wastes generated in the production of three different types of plastics were selected for experimentation. The first of these was a sludge from the primary treatment of polyvinyl chloride process waste water. This waste contained 9.7 percent total solids and 1.05 percent ash or inorganic residue. The solids from this waste had a heating value of 5610 Btu/lb.

A similar waste from the plastic industry selected for experimentation was sludge from the primary treatment of styrene process waste waters. This material contained 9.3 percent total solids and 0.51 percent ash. The heating value of the solids portion of this material was 14,970 Btu/lb.

In addition to the primary treatment sludges, several types of solid and liquid wastes were selected from the production of laminated plastics in the hope that a mixture suitable (pumpable) for feeding to the incinerator could be prepared. These wastes included: (1) sanding dust, (2) resin production reaction water, (3) waste solvents, and (4) waste resins. The heating value of the dust fraction alone was in excess of 9,000 Btu/lb.

Rubber

On the basis of the characterization and analysis of the samples obtained from the rubber industry two types of waste were selected for experimentation in the fluidized-bed incinerator. These were: (1) concentrated digestor wastes from rubber reclaiming operations, and (2) synthetic rubber production sludges after coagulation/flotation. The digestor waste contained 2.5 percent solids and 0.16 percent ash and had a heating value of 9,820 Btu/lb. The sludge from synthetic rubber production contained about 15.4 percent solids and 8.8 percent ash. The heating value of the dried solids was 14,950 Btu/lb.

Textiles

The only waste materials from the textile industry that appeared to be suitable for fluidized-bed incineration was the waste from viscose rayon production. The viscose rayon waste contained 23 percent solids and about 9 percent ash. The heating value of the solids was 4,415 Btu/lb.

SECTION V

EXPERIMENTAL WORK

Description of Equipment

A detailed sketch of the fluidized-bed incinerator unit and auxiliary equipment which was used during this program is shown in Figure 1. The fluidized-bed incinerator had an inside diameter of 10 inches in the bed zone. The freeboard area tapered from 10 inches diameter at the bed level to 16 inches diameter at the gas exhaust port, with an overall height of 72 inches. The unit was lined with 6 inches of castable insulating refractory and had a 3/8-inch-thick stainless steel orifice plate containing thirteen 1/4-inch-diameter orifice tubes. The orifice tubes were constructed in such a manner (tee types) as to prevent the bed material from running into the windbox during shut-down.

The fluidized-bed unit was mounted on a windbox combustion chamber in which natural gas was burned and mixed with excess air to provide a mixture of gases at a controlled temperature. These gases passed through the orifice plate to fluidize the solid bed material and in some cases provided a portion of the heat required for incineration of the wastes. The dust-laden exhaust gases from the bed were discharged through a 2-inch opening in the top of the unit into a cyclone dust collection system. After the cyclone, the gases passed through a Venturi-type scrubber and then through an entrainment separator. The mixture of solids and liquid from the entrainment separator flowed into a sump which provided a water seal for the slurry discharge system. The effluent from this sump was overflowed to waste or recycled to the scrubber. The gases emerging from the entrainment separator were exhausted from the building through a 2-inch line.

Thermocouples and pressure taps were placed at strategic points in the system to measure temperatures of inlet gases, bed material, freeboard space, and off-gas stream; and pressure differentials across the entire system, the bed zone, and the dust collection system. The temperature of the bed was controlled during incineration by varying the flow of natural gas and/or the rate of introduction of the particular waste material into the unit.

The waste material was pumped to a pneumatic feed gun mounted on the side of the incinerator using either a Moyno pump or a Sigmamotor pump. The feed gun was a single-barrel type discharging in the bed zone below the top of the bed. The waste material was dispersed into droplets of the desired size by varying the amount of air to this gun.

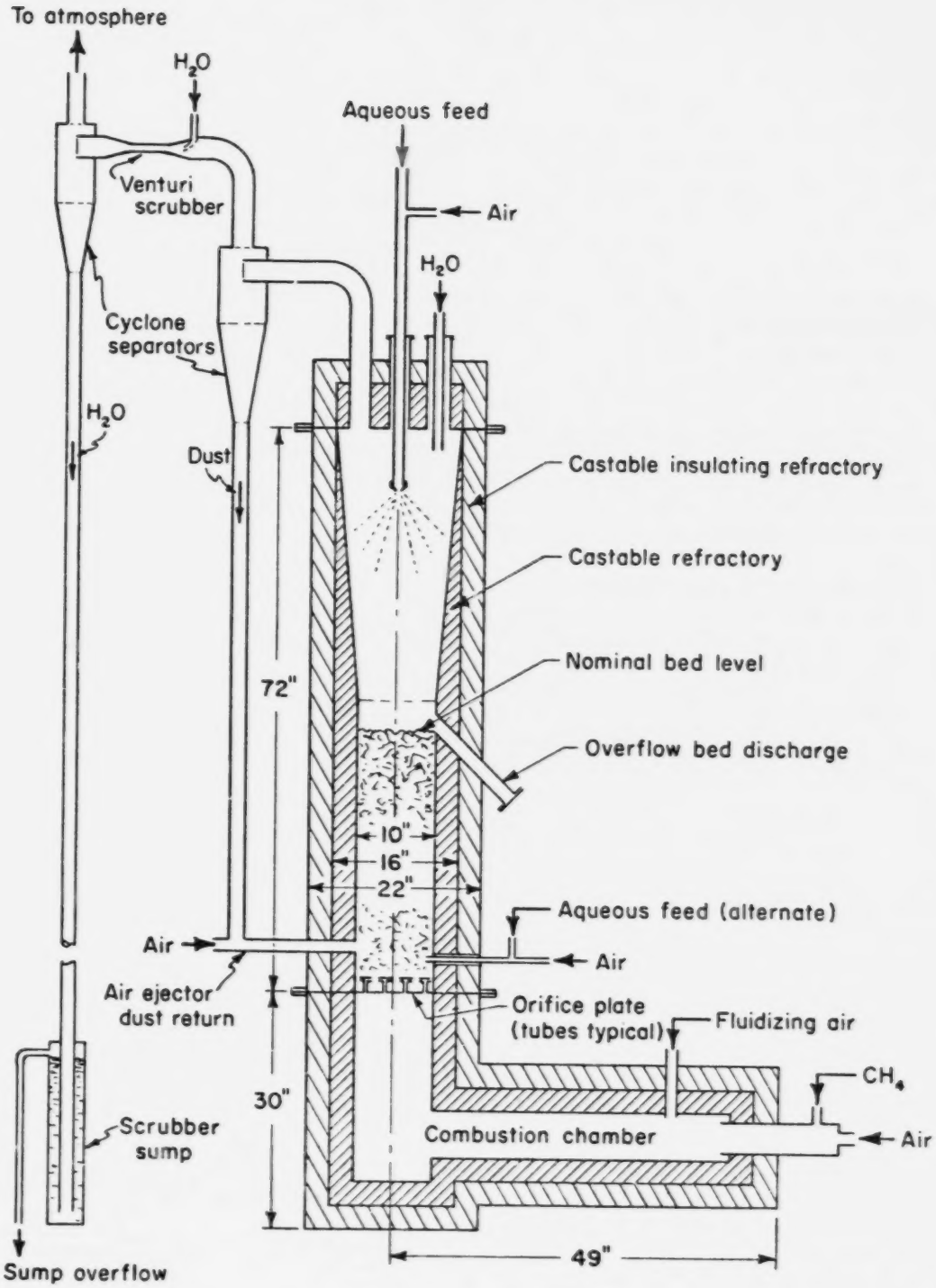

FIGURE 1. SKETCH OF 10-INCH-DIAMETER FLUIDIZED-BED UNIT

The solid residue, or ash, from the waste material was discharged from the incinerator as dust from the cyclone.

General Experimental Procedure

The general experimental procedure that was followed during the program consisted of

1. A starter bed of minus 20 plus 100 mesh sand was placed in the incinerator.

2. A flow of air sufficient to fluidize the starter bed was introduced.

3. Sufficient natural gas was metered to the combustion chamber to provide the heat required to raise the temperature of the bed material to a level sufficient for ignition of the carbonaceous content of the waste material.

4. The natural gas flow rate was adjusted to maintain the desired windbox temperature.

5. The flow of waste material into the incinerator was adjusted to maintain proper incineration temperature.

After equilibrium conditions of operation had been established, samples were collected of the residue, or ash, in the cyclone; effluent from the scrubber sump; and exhaust gases. Analyses performed on the various samples included the following:

1. Cyclone dust
a. mercury content
b. total carbon content
c. trace metals content

2. Scrubber effluent
a. total solids content
b. COD
c. mercury content
d. total organic carbon

3. Exhaust gases
a. sulfur compounds
b. hydrocarbons
c. mercury compounds.

Experimental Results

Several preliminary experiments were conducted in the 10-inch-diameter fluidized-bed incinerator on waste materials from each of the four industries. These preliminary runs were made to check out the physical operation of the system and to develop operating parameters for incineration of the various wastes. A suitable feeding system also was developed during this time. After these preliminary runs, a program was initiated in which selected wastes from each of the four industries were incinerated. The experimental conditions used and the results obtained from incineration of the various wastes are discussed in the following sections.

Experiments on Paint Waste

The wastes from the paint industry selected for experimental incineration were received in 55-gallon drums. During the preliminary experimentation several brief runs were made in which sludge or still bottoms from a solvent recovery operation were incinerated. The experimental conditions are shown in Table 15. As can be seen, the incineration or bed temperature was varied from 1300 to 1840 F to determine at which temperature the organics in the waste would be completely destroyed. The rate of introduction of wastes to the incinerator and in turn the available oxygen also was varied. These wastes were introduced directly into the bed through a feed gun mounted in the side of the unit. During these brief runs, it was found that once the wastes started burning no auxiliary fuel was required for incineration. That is, the incineration could be carried out autogenously.

Samples of the exhaust gases from selected runs were taken and analyzed for the components listed above. The results of these analyses, shown in Table 16, indicate that sulfur compounds as well as hydrocarbons were below 2 ppm, and NOx was less than 5 ppm even at incineration temperatures as low as 1300 F.

After the brief preliminary runs, several pilot-scale type runs (extended operation) were made feeding still bottoms from two solvent recovery plants and a sample of latex wash-out water. An additional run was made in which "decanter water" or water of reaction from resin production was used as freeboard cooling water while incinerating still bottoms. A summary of data from these experiments is given in Table 17.

The results of analyses of the residue from the experimental runs made on paint wastes are shown in Table 18. As shown, the mercury content of these materials is quite low (0.36 ppm or less). In most cases the total carbon content of the residue was also low (1.6 percent or less). The low carbon content is indicative of the high degree of completeness of combustion of the organic compounds present.

TABLE 15. EXPERIMENTAL CONDITIONS EMPLOYED DURING THE PRELIMINARY RUNS ON INCINERATION OF STILL BOTTOMS

Run Number	Temperature, F	Feed Rate, g/min	Total Feed, lb	Cooling Water, ml/min	Superficial Velocity, ft/sec	Oxygen Content of Exhaust Gas Value, %
1	1300	72.2	--	325	2.4	4.5
2	1400	62.8	4.05	240	2.5	8.5
3	1500	65.4	8.13	240	2.5	8.0
4	1500	72.2	--	235	2.7	5.0
5	1550	15.7	0.72	0	2.8	16.0
6	1600	73.2	5.26	118	2.9	6.0
7	1720	78.4	1.20	118	3.1	7.8
8	1840	72.2	--	120	3.2	5.5

TABLE 16. MASS SPECTROGRAPHIC ANALYSES OF EXHAUST GASES PRODUCED FROM PRELIMINARY EXPERIMENTAL INCINERATION OF STILL BOTTOMS

Run	Incineration Temperature, F	Oxygen Content of Exhaust Gas, volume percent	Volume Percent					Parts Per Million		
			CO_2	A	O_2	N_2	CO	CH_4	C_2H_2	C_2H_6
1	1300	4.5	14.1	0.94	3.26	81.7	0.02	82	450	40
4	1500	5.0	13.8	0.93	3.49	81.5	0.14	19	15	100
8	1840	5.5	13.8	0.91	3.54	81.6	0.14	2	100	33
7	1720	7.8	12.2	0.91	5.25	81.5	0.11	< 1	300	100

Note: All samples contained less than 2 ppm each of SO_2, COS, and H_2S; less than 5 ppm NO_x; and less than 1 ppm each of C_3 and C_4 hydrocarbons.

TABLE 17. EXPERIMENTAL CONDITIONS EMPLOYED DURING INCINERATION OF PAINT MANUFACTURING WASTES

Run Number	Description of Wastes Fed to Incinerator	Incinerator Temperature, F	Fluidizing Velocity, ft/sec	Exhaust Gas, O_2, percent	Fuel Required, cfm	Feed	
						Rate, g/min	Total, lb
17	Solvent recovery sludge	1350	1.5	8.0	None	19.3	10.2
18	ditto	1850	1.5	5.8	None	51.5	20.4
21	"	1820	1.5	7.1	None	50.3	42.0
22	"	1520	1.5	8.8	None	41.8	40.4
23(a)	"	1700	1.6	7.4	None	39.5	17.0
26	Latex washout water	1400	2.0	6.0	1.2	81.2	38.0
27	ditto	1750	2.3	2.2	1.8	41.8	17.0
28	Solvent recovery sludge	1350	1.6	7.0-9.0	None	38.0	153
29	ditto	1750	1.9	4.0-5.0	None	47.0	127
29-A	"	1750	2.4	6.0-8.0	None	38.0	65
30	Latex washout water	1750	1.5-2.0	3.0-4.0	1.8	57.0	410
33	Solvent recovery sludge	1750	2.0	6.0-8.0	None	53.0	116

(a) During this run "decanter water" from resin production was used as cooling water at a rate of 138 g/min.

TABLE 18. ANALYSES OF RESIDUES FROM THE FLUIDIZED-BED INCINERATION OF PAINT MANUFACTURING WASTES

Component	Run Number										
	17	18	21	22	26	27	28	29	29-A	30	33
Mercury, ppm	0.12	0.26	0.05	0.07	0.05	0.08	0.36	0.15	0.03	0.06	0.03
Total carbon, %	0.71	0.41	0.05	0.04	0.37	0.18	0.91	0.61	0.06	1.6	0.14
Loss on Ignition, %	7.38	4.32	1.18	0.87	1.5	1.3	1.97	1.95	0.65	9.34	1.85
Calcium, %	10-20	5-10	5-10	5-10	5-15	5-15	5-10	5-10	5-10	10-20	3-6
Aluminum, %	2-4	2-4	1.0	1.0	0.5	0.5	2.0	2.0	2.0	0.3	0.4
Titanium, %	0.2	5-10	10-20	10-20	0.4	0.3	10-20	10-20	10-20	1.0	3-6
Iron, %	2.0	3-6	3.0	3.0	0.4	0.3	3.0	5.0	5.0	0.2	2.0
Silica, %	10-20	5-15	5-10	5-10	10-20	10-20	10-20	5-10	5-10	10-20	20-40
Magnesium, %	3.0	1.0	3.0	3.0	0.3	0.3	2.0	2.0	1.0	0.2	0.5
Lead, %	2.0	5-10	0.3	0.3	0.03	0.03	0.3	0.4	0.4	0.01	0.6
Manganese, %	0.04	0.1	0.01	0.01	N.D.	N.D.	0.1	0.2	0.2	<0.01	0.3
Barium, %	0.02	0.03	0.1	0.1	N.D.	N.D.	0.03	0.1	0.1	<0.01	0.02
Antimony, %	<0.03	<0.03	0.3	0.3	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Chromium, %	0.4	2.0	0.2	0.2	15-30	15-30	2.0	0.3	0.3	10-20	1.0
Nickel, %	0.07	0.2	0.03	0.03	0.02	0.01	0.04	0.05	0.05	<0.01	0.02
Molybdenum, %	0.03	0.03	<0.01	<0.01	<0.005	<0.005	0.01	0.01	0.01	<0.005	0.02
Tin, %	<0.01	<0.01	0.01	0.01	N.D.	N.D.	0.01	<0.01	<0.01	<0.01	0.03
Copper, %	0.02	0.04	0.08	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.01
Zinc, %	0.3	0.3	1.0	1.0	N.D.	N.D.	0.2	0.3	0.3	<0.1	<0.1
Sodium, %	0.5	0.3	<0.1	<0.1	0.1	0.1	0.3	1.0	1.0	0.1	<0.1
Zirconium, %	0.05	0.2	0.02	0.02	N.D.	N.D.	0.05	0.1	0.1	<0.01	0.01
Cobalt, %	<0.01	0.02	<0.01	<0.01	0.02	0.02	0.01	0.02	0.02	0.02	0.1
Strontium, %	0.5	0.2	0.01	0.02	N.D.	N.D.	0.2	0.1	0.1	<0.01	0.03
Vanadium, %	N.D.	N.D.	N.D.	N.D.	0.01	0.01	N.D.	N.D.	N.D.	N.D.	N.D.
Potassium, %	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.4	0.6	0.4	0.1	0.1

N.D. = None detected.

The spectrographic analyses show that the major elements present in the residue from incineration of these paint wastes were calcium, silica, titanium, iron, lead and magnesium. The residue from the incineration of wash-out water from latex paint production (Runs 26 and 27) contained large quantities (15-30 percent) of chromium.

The effluent from the exhaust gas scrubber was analyzed for mercury, COD and total organic carbon. The results of these analyses are shown in Table 19. In all runs except 17 and 18 the mercury level was found

TABLE 19. ANALYSES OF EXHAUST GAS SCRUBBER EFFLUENT FROM THE FLUIDIZED-BED INCINERATION OF PAINT MANUFACTURING WASTES

Run Number	Mercury, mg/l	COD, mg/l	Total Organic Carbon, mg/l
17	6.9	24	10
18	1.1	29	10
21	< 0.1	25	8
22	0.6	28	9
26	< 0.005	18	N.A.
27	< 0.005	24	N.A.
28	0.010	N.A.	N.A.
29	0.002	N.A.	N.A.
29-A	< 0.001	N.A.	N.A.
30	< 0.001	N.A.	N.A.
33	< 0.001	N.A.	N.A.

N.A. = Not analyzed

to be less than 1 milligram per liter, COD less than 30 milligrams per liter and the total organic carbon less than 10 milligrams per liter. The influent water used for scrubbing the gases was also analyzed and found to contain less than 0.001 milligram per liter of mercury and 8 milligrams per liter total organic carbo.

Samples were taken of the exhaust gases and analyzed by mass spectrographic techniques. The results of these analyses are shown in Table 20. The most important noxious or toxic compounds found were hydrogen cyanide, and nitrous oxides. It is expected that hydrogen cyanide comes from the phthalocyanine that is used as a pigment in some blue and green paints.

TABLE 20. MASS SPECTROGRAPHIC ANALYSIS OF EXHAUST GASES FROM FLUIDIZED-BED INCINERATION OF PAINT MANUFACTURING WASTES

Components	Run 17	Run 18	Run 21	Run 22	Run 26	Run 27	Run 28	Run 29	Run 30	Run 33
Carbon dioxide, vol %	10.7	12.4	10.6	8.09	10.5	10.5	7.64	11.6	8.9	12.0
Argon, vol %	1.0	1.0	0.95	0.96	1.05	1.05	0.95	0.97	1.0	1.0
Oxygen, vol %	7.41	5.47	7.13	10.06	2.59	2.49	11.6	6.96	5.83	5.75
Nitrogen, vol %	80.8	80.9	81.1	80.1	85.8	85.7	79.8	80.4	84.1	81.1
Hydrogen, vol %	0.08	0.03	0.04	0.03	0.08	0.16	0.05	0.03	0.01	0.05
Carbon monoxide, vol %	0.21	0.02	0.06	0.02	0.02	0.08	0.03	0.002		<0.001
Methane, vol %	<0.001	<0.001	<0.001	<0.001	0.003	0.05	<0.002	<0.002		<0.001
Sulfur dioxide, ppm	<2	<2	N.D.	N.D.	<2	<2	<2	<2	<2	N.D.
Hydrogen sulfide, ppm	<2	<2	N.D.	N.D.	<2	<2	<2	<2	<2	N.D.
Carbonyl sulfide, ppm	<2	<2	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	<2	N.D.
Ethane, ppm	37	9	N.D.	N.D.	25	N.D.	N.D.	N.D.	N.D.	N.D.
Hydrogen cyanide, ppm	50	39	46	103	N.D.	N.D.	51	12	N.D.	20
Benzene, ppm	13	3	130	<2	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Nitrous oxide, ppm	28	45	21	57	53	N.D.	63	34	<10	185
Acetone, ppm	26	3	N.D.	N.D.	N.D.	N.D.	26	18	N.D.	N.D.
Ethane, ppm	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Ethylene, ppm	N.D.	N.D.	<2	<2	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Acetylene, ppm	N.D.	N.D.	<2	<2	N.D.	65	N.D.	N.D.	N.D.	N.D.

N.D. = None detected.

During Runs 17 and 21, samples of exhaust gas were taken using a steel bulb that could be heated during analysis. This was done in an effort to determine the mercury content of the gases by means of mass spectrography. In the sample from Run 17, no mercury was detected at a limit of 5 ppm. However, by concentrating the sample from Run 21, a detection limit of 0.1 ppm was achieved. No mercury was found at this level either.

Experiments on Plastic Wastes

Experimental incineration was carried out on two types of waste from the plastic manufacturing industry. Both were sludges from the primary treatment of process wastes. One sludge was from styrene production (Runs 15, 16, 19, 20, and 31), and the other from production of polyvinyl chloride (Runs 24, 25, and 32). Table 21 shows the operating conditions used for the incineration of these sludges. The sludges were fed directly into the bed via a feed gun mounted in the side of the unit.

Following the procedure for paint wastes, the residue after incineration was analyzed. The results of these analyses are given in Table 22. The analyses show that the residue contains very little (0.13 ppm or less) mercury and the total carbon content is also quite low (1.54 percent or less). The major elements found in the residue are silica, calcium, aluminum and magnesium, which probably come from the lime, and aluminum, iron, and magnesium salts used for coagulation in the primary treatment process.

Exhaust gas scrubber effluent was analyzed for mercury content and found to contain less than the detection limits of 0.001 ppm. The COD of the effluent was quite low except from the runs in which the PVC waste were incinerated. This could be due, in part, to the chloride content of the effluent. These analyses are presented in Table 23.

Analyses of the exhaust gases from the incineration of plastic waste is shown in Table 24. The gases are quite clean except in Run 25 which contained benzene, ethylene, toluene, and acetylene. The reason for this is not known, and it is assumed that complete combustion was not occurring at the time the sample was taken.

An attempt was made to blend several types of wastes (liquids and solids) from the production of laminated plastics. Even after dilution with large quantities of water this blend could not be fed to the incinerator. The mixture was not homogeneous and therefore could not be pumped with the equipment customarily used for this purpose. The wastes involved were (1) sanding dust, (2) resin production water of reaction, (3) waste solvents, and (4) waste treaters and resins. It is felt that these wastes could be incinerated if a suitable feeding system were to be developed.

TABLE 21. EXPERIMENTAL CONDITIONS EMPLOYED DURING INCINERATION OF PLASTIC MANUFACTURING WASTES

Run Number	Description of Wastes Fed to Incinerator	Incineration Temperature, F	Fluidizing Velocity, ft/sec	Exhaust Gas, O_2, percent	Fuel Required, cfm	Feed	
						Rate, g/min	Total, lbs
15	Primary treatment sludge	1330	1.5	6.0	1.1	95.5	50.5
16	Primary treatment sludge	1580	1.5	3.6	1.1	84.7	27.4
19	Primary treatment sludge	1350	1.5	5.5	0.8	78.5	41.2
20	Primary treatment sludge	1720	1.5	4.8	0.3	92.7	50.0
24	Primary treatment sludge (PVC)	1325	1.8	3.3	1.0	101.5	43.0
25	Primary treatment sludge (PVC)	1800	2.2	2.8	2.0	98.6	42.0
31	Primary treatment sludge	1750	1.8	4.0-5.0	1.0	60.0	298
32	Primary treatment sludge (PVC)	1350	2.1	3.0-4.0	1.0	68.0	360

TABLE 22. ANALYSES OF RESIDUE FROM FLUIDIZED-BED INCINERATION OF PLASTIC MANUFACTURING WASTES

Component	Run 15	Run 16	Run 19	Run 20	Run 24	Run 25	Run 31	Run 32
Mercury, ppm	0.13	0.10	0.08	0.06	0.10	0.06	0.06	0.04
Total carbon, %	1.54	0.91	1.33	0.32	0.04	0.02	3.0	0.19
Loss on Ignition, %	4.49	2.35	4.75	1.27	0.49	0.71	16.9	2.38
Chromium, %	0.03	0.03	0.1	0.03	0.1	0.1	1.0	1.0
Silica, %	10-20	10-20	10-20	10-20	20-40	20-40	5.10	20.40
Calcium, %	10-20	10-20	10-20	10-20	5.0	2.0	15.30	5-10
Aluminum, %	3-5	3-5	2-4	2-4	0.2	0.7	3-5	2.0
Lead, %	0.08	0.08	0.7	0.2	0.1	0.03	0.01	0.01
Magnesium, %	2.0	2.0	2.0	2.0	0.5	0.2	3.0	0.5
Iron, %	3.0	3.0	1.0	1.0	2.0	1.0	2.0	1.0
Vanadium, %	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Nickel, %	0.03	0.07	0.03	0.01	0.03	0.03	0.01	0.01
Molybdenum, %	0.03	0.03	0.01	0.01	<0.01	<0.01	<0.01	<0.01
Copper, %	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.005
Sodium, %	0.5	0.5	0.3	0.3	N.D.	N.D.	1.0	0.2
Titanium, %	0.5	0.5	0.3	0.1	1-2	0.5	0.2	2.0
Cobalt, %	<0.01	<0.01	<0.01	<0.01	N.D.	N.D.	<0.01	<0.01
Zinc, %	0.1	0.1	0.1	<0.1	0.2	0.1	<0.1	<0.1
Barium, %	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01
Boron, %	N.D.	N.D.	N.D.	N.D.	0.01	<0.01	N.D.	N.D.
Manganese, %	0.04	0.04	0.03	0.03	0.02	0.01	0.03	0.02
Tin, %	<0.01	<0.01	<0.01	<0.01	0.02	0.01	<0.01	0.03
Potassium, %	N.D.	N.D.	N.D.	N.D.	0.2	0.1	0.4	0.2
Phosphorus, %	N.D.	N.D.	N.D.	N.D.	1.3	0.5	N.D.	N.D.
Zirconium, %	0.02	0.05	0.02	0.01	0.01	0.01	<0.01	0.01
Strontium, %	0.02	0.02	0.03	0.01	N.D.	N.D.	0.01	0.01
Antimony, %	0.03	<0.03	<0.03	<0.03	N.D.	N.D.	N.D.	N.D.

N.D. = None detected.

TABLE 23. ANALYSES OF EXHAUST GAS SCRUBBER EFFLUENT FROM FLUIDIZED-BED INCINERATION OF PLASTIC MANUFACTURING WASTES

Run Number	Total Solids, mg/l	Total Organic Carbon, mg/l	Mercury mg/l	COD mg/l
15	493	8.0	<0.0001	10
16	510	8.0	<0.0001	16
19	463	6.0	<0.0001	7
20	451	6.0	<0.0001	2
24	N.A.	8.0	<0.0001	156
25	N.A.	30.0	<0.0001	127
31	N.A.	N.A.	<0.0001	N.A.
32	N.A.	N.A.	<0.0001	N.A.

N. A. = Not analyzed.

TABLE 24. MASS SPECTROGRAPHIC ANALYSES OF EXHAUST GASES FROM THE FLUIDIZED-BED INCINERATION OF PLASTIC MANUFACTURING WASTES

Component	Run 15	Run 16	Run 19	Run 20	Run 24	Run 25	Run 31	Run 32
Carbon dioxide, vol %	8.67	11.5	10.1	9.7	10.9	9.68	11.2	10.3
Argon, vol %	1.01	1.01	0.99	0.99	1.06	0.93	1.03	1.02
Oxygen, vol %	6.56	1.74	3.24	4.65	2.91	0.33	4.11	4.28
Nitrogen, vol %	83.6	85.5	85.5	84.1	85.0	75.6	83.6	83.5
Hydrogen, vol %	0.14	0.29	0.09	0.09	0.09	4.39	0.05	<0.01
Carbon monoxide, vol %	<0.01	0.07	0.03	<0.01	0.015	2.59	N.D.	<0.01
Methane, vol %	<0.01	0.02	<0.01	<0.01	<.01	5.99	N.D.	<0.01
Ethane, ppm	18	38	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Benzene, ppm	N.D.	3	<2	10	N.D.	200	N.D.	N.D.
Ethylene, ppm	N.D.	N.D.	8	<2	11	1100	N.D.	N.D.
Acetylene, ppm	N.D.	N.D.	8	<2	N.D.	2900	N.D.	N.D.
Toluene, ppm	N.D.	N.D.	N.D.	N.D.	N.D.	50	N.D.	N.D.
Nitrous oxide, ppm	15	980	5	37	N.D.	N.D.	N.D.	N.D.
Hydrogen cyanide, ppm	N.D.	N.D.	<2	<2	N.D.	N.D.	N.D.	N.D.
Sulfur dioxide, ppm	<2	<2	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Carbonyl sulfide, ppm	<2	<2	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Hydrogen sulfide, ppm	<2	<2	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

Note: N.D. = None detected.

TABLE 25. EXPERIMENTAL CONDITIONS EMPLOYED DURING INCINERATION OF RUBBER MANUFACTURING WASTES

Run Number	Description of Wastes Fed to Incinerator	Incinerator Temperature, F	Fluidizing Velocity, ft/sec	Exhaust Gas, O_2, percent	Fuel Required, cfm	Feed	
						Rate, g/min	Total, lb
35	Primary treatment sludge	1250	1.7	6.0	2.0	70	14.0
36	ditto	1450	1.9	4.8	2.6	22	6.5
37(a)	"	1400	2.0	5.1	2.0	63	44
38	"	1450	2.0	4.7	2.4	63	48

(a) During this run secondary sewage effluent was used as scrubbing media in the exhaust gas scrubber.

Experiments on Rubber Wastes

Two wastes from the rubber industry were selected for experimental incineration; however, one of them, a sample of concentrated digestor waste from a rubber reclaiming operation was never received. Four separate runs were made on the sludge from the primary treatment of synthetic rubber manufacturing wastes. The primary treatment involves coagulation and flotation; therefore, the waste is actually a flotation product. Table 25 summarizes the conditions used for incineration of this waste. In all of these runs the sludges were introduced into the bed through a feed gun mounted in the side of the unit. During Run Number 37 secondary sewage effluent was used as the scrubbing media. This was done to see if the sewage effluent would scrub the gases as well as water. The analysis of the exhaust gases show very little, if any, difference in gas quality.

The analyses of the scrubber effluent as well as the secondary effluent used are shown in Table 26. It can be seen that the mercury content in Run 37 was not significantly higher than in Run 38 even though the scrubbing media used (secondary sewage effluent) contained 0.002 ppm. However, the COD of the run (Number 37) using sewage effluent was considerably higher. The high COD content of the scrubber effluent from Run 35 was probably due to the low (1250 F) incineration temperature.

TABLE 26. ANALYSES OF EXHAUST GAS SCRUBBER EFFLUENT FROM FLUIDIZED-BED INCINERATION OF RUBBER MANUFACTURING WASTES

Run Number	Mercury, mg/l	COD, mg/l
35	0.0008	1480
36	0.0034	190
37	0.012	211
38	0.011	37
Secondary sewage effluent	0.002	36

The results of the analyses of the residue from incineration of rubber wastes, shown in Table 27, indicate a high mercury content (3 and 5 ppm) for Runs 37 and 38. However, the total carbon content was low (less than 0.43 percent) in both cases, which indicated that almost complete combustion had occurred. As was the case with the residue from plastic processing waste, the major elements present were silica, calcium, aluminum, iron, and magnesium.

TABLE 27. ANALYSES OF RESIDUE FROM FLUIDIZED-BED INCINERATION OF RUBBER MANUFACTURING WASTES

Component	Run 35	Run 36	Run 37	Run 38
Mercury, ppm	0.40	0.30	5	3
Total carbon, %	2.65	0.95	0.43	0.39
Loss on Ignition, %	20.2	18.1	7.3	1.7
Aluminum, %	10-20	10-20	10-20	15-30
Silica, %	3-5	4-8	10-20	5-15
Magnesium, %	2-4	2-4	0.7	1.0
Calcium, %	3-5	3-5	2.0	2.0
Iron, %	1-2	1-2	1-2	1-2
Lead, %	0.2	0.2	0.3	0.2
Chromium, %	0.5	0.5	0.4	0.8
Boron, %	0.05	0.05	<0.01	<0.01
Barium, %	0.01	0.01	0.01	0.01
Manganese, %	0.02	0.02	0.01	0.01
Nickel, %	0.01	0.01	0.02	0.02
Molybdenum, %	<0.005	0.01	0.005	<0.005
Vanadium, %	0.01	0.01	0.02	0.03
Copper, %	0.01	0.01	0.01	0.02
Sodium, %	<0.1	<0.1	<0.1	<0.1
Titanium, %	0.7	0.7	0.7	0.4
Zirconium, %	0.01	0.01	<0.01	<0.01
Cobalt, %	0.01	0.01	0.01	0.005
Potassium, %	0.3	0.3	0.3	0.3

Analyses of the exhaust gases from incineration of rubber manufacturing wastes indicated that very little, if any, noxious or toxic gases were produced. These data are presented in Table 28. The only components of any significance were hydrogen cyanide (Run 37) and nitrous oxide (Runs 35 and 36).

Experiments on Textile Wastes

Due to the small amount of textile manufacturing in the State of Ohio, only one waste was incinerated. This is a waste from a viscose process. Table 29 gives the experimental operating conditions used for incineration of this material. This waste was introduced into the bed via a feed gun mounted in the side of the unit. Due to the presence of caustic in this waste, attempts to operate at bed temperatures above 1250 F caused the bed material to become sticky and defluidize. Therefore, combustion was not complete as is witnessed by the high total carbon and loss on ignition analyses shown in Table 30. It should also be noted in these data that this residue contained from 30 to 60 percent sodium.

Analyses of the scrubber effluent indicate that very little pollutional contaminants are present in this stream. The mercury content of less than 0.001 milligram per liter and the COD of 1 milligram per liter point this out. These analyses are shown in Table 31.

Table 32 presents the results of mass spectrographic analysis of the exhaust gases from the fluidized-bed incineration of the viscose process wastes. The nitrogen oxide content of these gases of 16 ppm probably was due to the low incineration temperature. However, even at the low temperature of combustion employed, the amount of sulfur compounds and hydrocarbons are quite low.

TABLE 28. MASS SPECTROGRAPHIC ANALYSIS OF EXHAUST GASES FROM THE FLUIDIZED-BED INCINERATION OF RUBBER MANUFACTURING WASTES

Component	Run 35	Run 36	Run 37	Run 38
Carbon dioxide, vol %	8.87	10.5	9.46	8.05
Argon, vol %	0.97	1.0	1.0	0.99
Oxygen, vol %	6.86	5.55	5.96	8.3
Nitrogen, vol %	82.4	82.9	83.5	81.4
Hydrogen, vol %	0.01	<0.01	0.07	0.04
Carbon monoxide, vol %	0.9	0.03	0.007	0.016
Sulfur dioxide, ppm	<3	<3	<3	<3
Hydrogen sulfide, ppm	<3	<3	N.D.	N.D.
Methane, ppm	<3	<3	N.D.	N.D.
Hydrogen chloride, ppm	<3	<3	<1	<1
Hydrogen cyanide, ppm	N.D.	N.D.	11	<3
Carbonyl sulfide, ppm	<3	<3	<1	<1
Nitrous oxide, ppm	10	10	<3	<3
Carbon disulfide, ppm	3	<3	<1	<1
Ethylene, ppm	100	<100	N.D.	N.D.

N.D. = None detected.

TABLE 29. EXPERIMENTAL CONDITIONS EMPLOYED DURING INCINERATION OF TEXTILE MANUFACTURING WASTES

Run Number	Description of Wastes Fed to Incinerator	Incinerator Temperature, F	Fluidizing Velocity, ft/sec	Exhaust Gas, O_2, percent	Fuel Required, cfm	Feed	
						Rate, g/min	Total lb
34	Viscose rayon wastes	1250	2.0-2.3	8.0-10.0	2.0	14	31

TABLE 30. ANALYSES OF RESIDUE FROM FLUIDIZED-BED INCINERATION OF TEXTILE MANUFACTURING WASTES

	Run 34--Viscose Waste
Mercury, ppm	0.07
Total Carbon, %	9.0
Loss on Ignition, %	21.3
Calcium, %	0.2
Silica, %	2.0
Chromium, %	0.03
Aluminum, %	0.05
Titanium, %	0.2
Iron, %	0.05
Magnesium, %	0.01
Lead, %	0.2
Barium, %	<0.01
Manganese, %	<0.01
Tin, %	0.01
Nickel, %	<0.01
Molybdenum, %	<0.005
Copper, %	<0.005
Zirconium, %	<0.01
Cobalt, %	0.01
Sodium, %	30-60
Zinc, %	<0.1
Potassium, %	1.0
Strontium, %	<0.01

TABLE 31. ANALYSES OF EXHAUST GAS SCRUBBER EFFLUENT FROM FLUIDIZED-BED INCINERATION OF TEXTILE WASTES

Run 34	Mercury, mg/l	COD, mg/l	Total Organic Carbon, mg/l
Viscose Waste	<0.001	N.A.	N.A.

N. A. = Not analyzed.

TABLE 32. MASS SPECTROGRAPHIC ANALYSIS OF EXHAUST GASES FROM FLUIDIZED-BED INCINERATION OF TEXTILE WASTES

Component	Run 34--Viscose Wastes
Carbon dioxide, vol %	5.26
Argon, vol %	1.02
Oxygen, vol %	11.6
Nitrogen, vol %	82.1
Hydrogen, vol %	0.02
Methane, vol %	<0.001
Carbon monoxide, vol %	0.03
Nitrous oxide, ppm	16
Sulfur compounds, ppm	<3
Hydrocarbons, ppm	<3

SECTION VI

DISCUSSION OF EXPERIMENTAL RESULTS

Paint

The results of the experimental work conducted on the fluidized-bed incineration of wastes from the manufacture of paint indicate that this type of incineration is technically feasible. The physical operation of the incineration system was quite good and very few operational problems were encountered. Early in the program, it was found that introduction of wastes into the incinerator under the bed rather than as an overhead spray gave improved results. This was due to the high volatile organic content of the wastes. Introduction of these wastes as an overhead spray did not afford sufficient retention time for complete combustion of the volatiles and organics.

During the incineration of the sludges from solvent recovery operations, it was necessary to use cooling water in the freeboard of the incinerator to prevent excessively high temperatures in this zone. This is due, primarily, to the high heating value of these wastes. In one of the experimental runs water of reaction from resin production was used as cooling water. This appears to be quite attractive, since two wastes are treated in one operation.

The incineration of the sludges from solvent recovery can be carried out autogenously, that is, without the use of auxiliary fuel, because of the high heating value of these wastes. In the incineration of the wash-out water from latex paint production fuel is required to elevate the temperature to a point where combustion will occur. The economics of this type of incineration is discussed in another section of this report.

Plastics

The experimentation on the fluidized-bed incineration of wastes from plastic production indicated that this too is technically feasible. The wastes incinerated experimentally, sludges from primary treatment of styrene and polyvinyl chloride process wastes, are amenable to fluidized-bed incineration. Even though these materials require auxiliary fuel for combustion, this method of incineration remains quite attractive since little or no noxious or toxic gases are produced.

The residue from the incineration of these wastes is a finely divided dust that could be disposed of in a landfill. They contain no organic

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compounds that could be leached out and cause stream pollution problems. There also is the possibility of recovering the calcium, iron, aluminum, or magnesium from this residue prior to disposal.

The only effluent stream from this type of incineration that might cause stream pollution is the scrubber effluent. However, in a commercial installation of this type the scrubbing water could be recycled to the scrubber to alleviate this problem.

Rubber

The results obtained from the experimentation on fluidized-bed incineration of wastes from rubber manufacturing indicate the technical feasibility of the technique for treating the wastes under consideration. However, the only waste incinerated from this area was the flotation sludge from the primary treatment of synthetic rubber production wastes. The concentrated digestor waste from rubber reclaiming that was selected for experimentation was not received.

The sludge from synthetic rubber production was incinerated under conditions which did not produce toxic or noxious gases. The effluent from the exhaust gas scrubber contained only trace contaminants. During Run Number 37 when secondary sewage effluent was used as scrubbing media, the COD level increased from 36 to 211 milligrams per liter. The mercury level increased during the run from 0.002 to 0.012 ppm.

The physical operation of the incineration system was quite good during these experimental runs.

Textiles

The only waste which could be procured from the textile industry that appeared suitable for incineration was the waste from a viscose process. From the data collected during the experimentation it would appear that complete combustion of the organics present in this waste is not possible by this technique. It is, however, possible to incinerate this particularly difficult waste material and achieve about 80 percent combustion. This would alleviate the potential pollution problem that now exists from disposal of this material in a landfill.

Complete combustion could not be attained because of the low melting point of this material requiring that the incinerator be operated at low temperatures. The low melting point is due to the high caustic content of this waste. Attempts to operate the incinerator at temperatures above this point caused the bed material (sand) to become sticky and defluidize. However, even though complete combustion was not achieved, partial incineration does not produce toxic or noxious gases.

SECTION VII

POTENTIAL IMPACT ON WATER POLLUTION

This section discusses the potential of the various wastes for pollution of streams and the reduction of same by incineration. The waste loads and their possible contribution to pollution is discussed separately in the following sections.

Paint

The plants involved in paint manufacture and related type operations in Ohio that were visited during this program generate about 110,000,000 gallons of various wastes annually. Of these wastes only 640,000 gallons are incinerated at the present time. The remaining wastes go either directly to city sewerage systems or landfill operations. The amount that is disposed of in landfill operations is only 470,000 gallons. This means that the various city sewage treatment plants must process over 98 percent of the wastes generated by this industry. Of course, a majority of these wastes are dilute process waters, such as cooling tower water, that presents no problems, except the tremendous volumes involved at the sewage treatment plants.

The results of the experimental program indicate that in the case of solvent-bearing wastes from the paint industry, the total waste load can be reduced considerably by fluidized-bed incineration. The average total waste remaining for disposal after incineration of solvent recovery sludges is about 3.5 percent of the original weight. The average chemical oxygen demand of this type waste is reduced from 547,250 mg/liter to essentially zero. However, the effluent from the scrubber used for cleaning the exhaust gases from the incinerator contains an average of about 24 mg/liter COD. This effluent could be recycled to the scrubber continuously and incinerated concurrently with the solvent-bearing wastes.

On the basis of a typical plant which generates about 125,000 gallons per year of solvent recovery sludge, the use of incineration would reduce COD loading to the environment by about 525,000 pounds per year for this plant. Assuming the plant to be representative of the national picture (see Figure A-1), a total reduction of 360,000,000 pounds of COD per year could be achieved in the United States.

Plastic

The plants visited that are involved in the manufacture of plastics generate approximately 900,000 gallons of liquid waste, 9,500,000

pounds of sludge from waste treatment facilities, and 35,000,000 pounds of solid waste annually. These wastes are all currently disposed of in landfill operations, and therefore create the possibility of stream pollution by leaching. The COD level of the solid wastes from these plants varies from 530,000 to 1,300,000 ppm. The liquid waste contained about 120,000 mg per liter COD and the waste treatment sludge from 250,000 to 590,000 mg per liter.

Incineration of the primary treatment sludges reduces the waste to be disposed of to less than 5 percent of the original weight. The residue from the liquid wastes would amount to only about 75 mg per liter and the residue from the solid waste would amount to only about 2 percent or less if they were incinerated. As was the case with incineration of the wastes from paint manufacture, the only COD in the products occurs in the scrubber effluent, which amounts to only about 8 mg per liter and this could be recycled and incinerated also.

Using as a basis a typical plant which generates 6,000,000 pounds per year of primary treatment sludge, the possible reduction in COD by incineration is about 3,500,000 pounds per year. Assuming this plant to be representative of the entire plastics industry nationally which consists of 340 plants (see Figure A-2), the total COD reduction for the United States would be about 1,200,000,000 pounds per year.

Rubber

Very little information was obtained on rubber manufacturing wastes in Ohio, although it was determined that the wastes vary considerably with COD values, ranging from 21,000 to 540,000 mg per liter for various sludges from primary treatment operations. The annual quantities of waste generated in this industry also was exceedingly difficult to assess.

On the basis of one large synthetic rubber manufacturing plant which provided quantities of flotation sludge for experimental studies, a possible reduction in COD by incineration was calculated at about 1,000,000 pounds annually. Projecting this to a national level which consists of only 28 plants (see Figure A-3), the total COD reduction would be about 88,000,000 pounds.

Textile

Since the textile industry in Ohio is relatively small, little data were obtained from this industry. Of the plants visited the major waste load appears to be dye wastes and process waters. These wastes are quite dilute (less than 1 percent solids) and are disposed of in city sewerage systems. The COD level varies from 355 to 751 mg per liter. By contrast,

another waste from the textile industry is viscose process waste which contained about 121,000 mg per liter COD.

Incineration of the dilute dye wastes would not be economically feasible because of the large quantities of water involved. Incineration of the viscose process waste should be considered because of the high COD content of this material. However, additional research is needed for the incineration of this particular waste to develop the proper operating parameters. No information was obtained on the quantities of viscose waste generated, but the amount probably is low since there are only 20 plants producing viscose in the United States (see Figure A-4).

SECTION VIII

PRELIMINARY ECONOMIC EVALUATION

To assess the economic feasibility of incineration for disposal of wastes in the paint, plastics, rubber, and textile industries, a preliminary evaluation was made of the process requirements and costs for three specific incineration systems. These systems were selected on the basis of experimental results and conclusions which indicated

(1) The technical feasibility of incineration of waste solvents and sludges from the paint industry using the heating value of these wastes as a prime source of energy. The envisaged process also would permit the incineration of certain other paint wastes such as reaction water and latex wash-out concurrently with the solvent bearing wastes. Flows would be adjusted so that autogenous operation could be achieved.

(2) The technical feasibility of incineration of sludges from plastic primary treatment operations. These sludges could contain either styrene or PVC polymers. On the basis of experimental results, it was determined that additional energy input would be needed for incineration of these sludges. This could be supplied by burning methane and/or fuel oil in a combustion zone or by using solid plastic wastes as a source of energy.

(3) The incineration of rubber manufacturing waste sludges with additional energy being supplied by combustion of methane and/or fuel oil.

The following sections discuss the design aspects of an incinerator which would be required for each of these three example systems.

Example I: Paint Waste Incineration Process

The envisaged process for the incineration of solvent recovery sludges, reaction waters, and latex wastes is illustrated in Figure 2. Capacity was based on the production of 125,000 gallons annually of solvent recovery sludge which had an average heating value of 120,000 Btu per gallon. Operating conditions were selected on the basis of experimental runs made during the study, (i.e., bed temperature 1750 F, superficial velocity 2.0 fps). The calculations made to determine material and energy balances shown in the Appendix indicate that an incinerator of about 6 feet in diameter would be required for this system. The results also indicate that approximately 54 gallons per hour of latex wastes and/or reaction water could be disposed of by incineration concurrently with the waste sludge.

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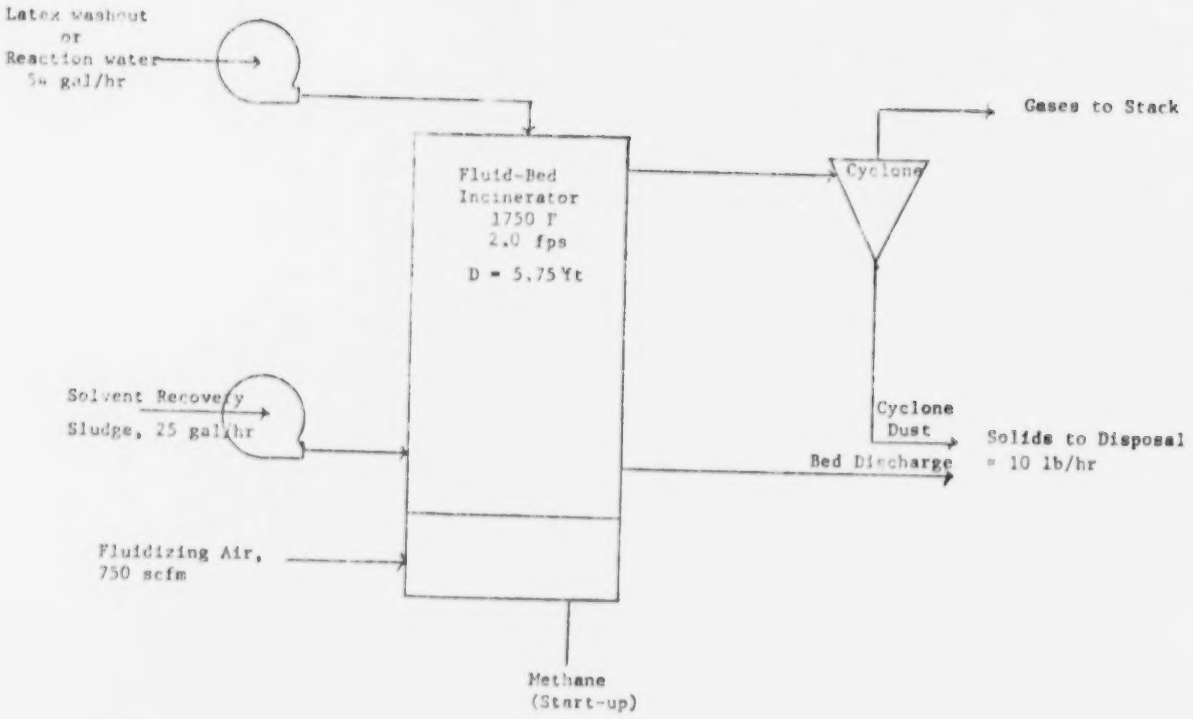

FIGURE 2. SIMPLIFIED FLOWSHEET OF INCINERATOR FOR PAINT WASTES

Example II: Plastic Waste Incineration Process

The envisaged process for the incineration of primary treatment sludge from plastic manufacture is illustrated in Figure 3. Capacity was based on the production of 30,000,000 pounds annually of sludge containing an average of 10 percent solids. The heating value of these solids was estimated at 15,000 Btu per pound. Operating conditions were selected on the basis of experimental runs which indicated a bed temperature of 1325 F and superficial velocity of 1.8 fps were required. The calculations made to determine material and energy requirements are shown in Appendix B. The results indicate that an incinerator of about 12 feet in diameter would be required for incineration of this waste sludge. Added fuel must be supplied (i.e., 156 scfm of methane or 625 pounds per hour of waste polymers).

Example III: Rubber Waste Incineration Process

A simplified flowsheet for incineration of a flotation sludge containing rubber wastes is shown in Figure 4. In this example system, no information was obtainable for a typical quantity of wastes generated by plants in Ohio. Thus, capacity was arbitrarily selected at 10,000,000 pounds annually. A typical sludge, however, is known to contain 15.4 percent solids which have a heating value of about 15,000 Btu per pound of dry solids. Operating conditions from experimental runs with this sludge would be bed temperature of 1400 F and superficial velocity of 2.0 fps. The results of design calculations (Appendix B) indicate this incinerator would be about 7.5 feet in diameter with provision for burning about 32 scfm of methane in a combustion chamber.

Estimated Capital and Operating Costs

The essential capital and operating costs for the three systems selected above are itemized in Table 33. Basically, the capital costs were estimated for conventional fluidized-bed units currently being manufactured by a number of companies. Operating costs were selected for the major items that were believed to be significant based on experience with these types of systems.

Generally, the cost data indicate that fluidized-bed incineration could be used for disposal of these wastes at an operating cost of between 140 to 180 dollars per day for plants generating between 3,000,000 and 30,000,000 pounds of waste annually. This reduces to a cost of between 0.1 to 1.0 cent per pound of waste being disposed of by incineration. The higher cost, for paint waste incineration, results from the use of a small diameter fluidized-bed unit and from the use of low feed rates necessary for the high heating value of these wastes.

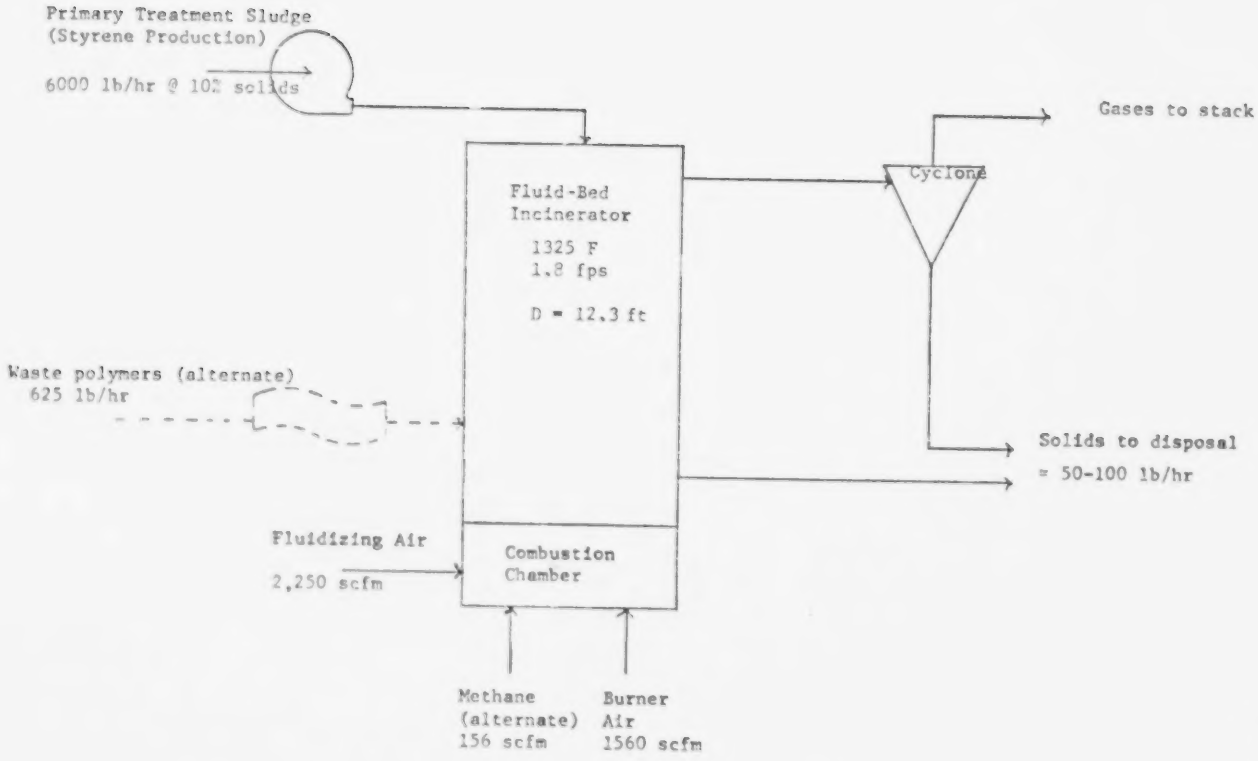

FIGURE 3. SIMPLIFIED FLOWSHEET OF INCINERATOR FOR PLASTIC WASTES

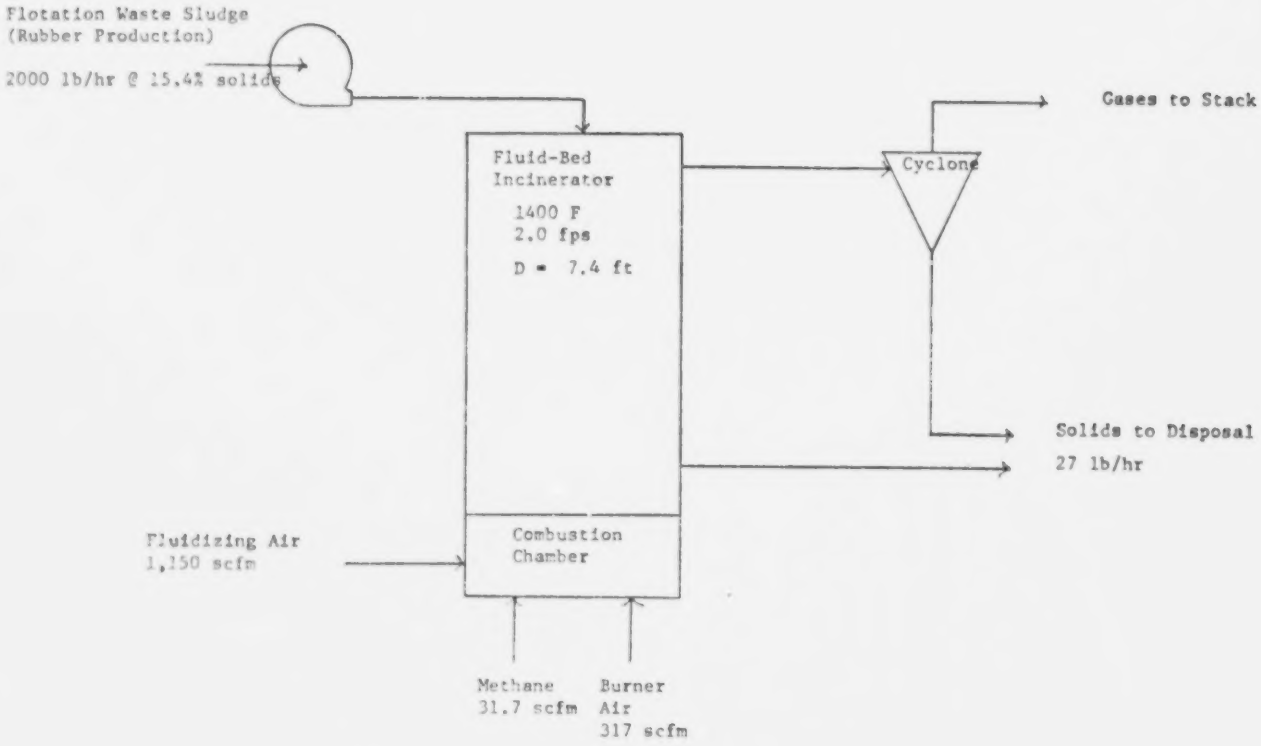

FIGURE 4. SIMPLIFIED FLOWSHEET OF INCINERATOR FOR RUBBER WASTES

TABLE 33. ESTIMATED CAPITAL AND OPERATING COST FOR EXAMPLE INCINERATION SYSTEMS

	Example I	Example II	Example II
Essential Plant Cost, $	$200,000	$350,000	$250,000
Essential Operating Costs, $/day			
1. Fuel @ $.25 per 10^6 Btu	0	0	4.10
2. Electric Power @ $.007/KWH	8.40	8.40	8.40
3. Supplies and Maintenance @ 0.003% of Plant Cost	6.00	10.50	7.50
4. Operating Labor @ 24 Man-hr per day, $3.50 per Man-hr	84.00	84.00	84.00
5. Amortization @ 0.0224% of Plant Cost	44.80	78.50	56.00
Total Operating Costs	143.20	181.40	160.00
Cost per Pound of Waste	1.1c	0.14c	0.40c

SECTION IX

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SECTION X

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FIGURE A-1. NUMBER AND DISTRIBUTION OF PAINT MANUFACTURING PLANTS IN UNITED STATES

FIGURE A-2. NUMBER AND DISTRIBUTION OF PLASTICS MANUFACTURING PLANTS IN UNITED STATES

FIGURE A-3. NUMBER AND DISTRIBUTION OF SYNTHETIC RUBBER MANUFACTURING PLANTS IN UNITED STATES

FIGURE A-4. NUMBER AND DISTRIBUTION OF VISCOSE RAYON PLANTS IN UNITED STATES

APPENDIX B

MATERIAL AND ENERGY BALANCE CALCULATIONS FOR EXAMPLE INCINERATION SYSTEMS

Example I: Paint Waste Incineration

Waste: 125,000 gallons annually, solvent recovery sludge

Operating Schedule: 100 hours/week, 50 week year

Conditions: Bed Temperature = 1750 F
Superficial Velocity = 2.0 fps

(1) Heat Input (steady-state operation)
Q = 25 gal/hr x 120,000 Btu/gal = 3,000,000 Btu/hr

(2) Fluidizing Air (assume volume in cu ft = $\frac{\text{Btu/hr}}{100}$, also assume 50% excess)

$$V = \frac{3,000,000}{100} \times 1.5 \times \frac{1}{60} = 750 \text{ scfm}$$

(3) Heat loss to gases ($Q = n C_p \Delta t$)
Q = 750 x 0.02 x 1680 x 60 = 1,500,000 Btu/hr

(4) Heat loss to reactor walls (assume 20% of heat input)
Q = 0.20 x 3,000,000 = 600,000 Btu/hr

(5) Reaction water or Latex feed (W x ΔH = excess heat input)

$$W = \frac{3,000,000 - 2,100,000}{2000} \times \frac{1}{8.345} = 54 \text{ gal/hr}$$

(6) Fluid bed diameter (area = gas flow/superficial velocity)

$$A = 750 \times \frac{1750 + 460}{530} \div 2.0 \times 60 = 26.1 \text{ ft}^2 \quad D = 5.75 \text{ ft.}$$

Example II: Plastic Waste Incineration

Basis: 30,000,000 pounds annually styrene primary treatment sludge @ 10% solids

Operating Schedule: 100 hours/week, 50 weeks/year

Conditions: Bed Temperature = 1325 F
Superficial Velocity = 1.8 fps

(1) Heat input from solids
$Q = 6{,}000 \text{ lb/hr} \times .10 \times 15{,}000 \text{ Btu/lb} = 9{,}000{,}000 \text{ Btu/hr}$

(2) Fluidizing air (assume volume in cu ft = $\frac{\text{Btu/hr}}{100}$, also assume 50% excess)
$V = \frac{9{,}000{,}000}{100} \times 1.5 \times \frac{1}{60} = 2250 \text{ scfm}$

(3) Heat requirements
Water = 6,000 lb/hr x .90 x 1660 Btu/lb = 8,960,000 Btu/hr
Fluid Air = 2250 x .02 x 1255 x 60 = 3,390,000 Btu/hr
Total (except loss to walls) 12,350,000 Btu/hr

(4) Auxiliary fuel needed (assume 20% heat loss to walls)
$0.8 \left[V_{CH_4} \times 1000 \text{ Btu/cf} + 9{,}000{,}000\right] = 12{,}350{,}000 + 0.2 \times (2250 + 1560) \times 18 V_{CH_4}$

$V_{CH_4} = \frac{5{,}150{,}000}{549} \times \frac{1}{60} = 156 \text{ scfm}$

V (waste polymers) = 625 lb/hr (alternate auxiliary fuel)

(5) Fluid bed diameter

$A = (2250 + 1560) \times \frac{1325 + 460}{530} \div 2.0 \times 60 = 119 \text{ ft}^2$

$D = 12.3 \text{ ft}$

Example III: Rubber Waste Incineration

Basis: 10,000,000 pounds annually (15.4% solids, 1.35% ash)

Operating Schedule: 100 hours/week, 50 weeks/year

Conditions: Bed Temperature = 1400 F
Superficial Velocity = 2.0 fps

(1) Heat input from solids
$Q = 2{,}000 \text{ lb/hr} \times .154 \times 15{,}000 \text{ Btu/lb} = 4{,}620{,}000 \text{ Btu/hr}$

(2) Fluidizing air (assume volume in cu ft = $\frac{\text{Btu/hr}}{100}$, also assume 50% excess)

$$V = \frac{4,620,000}{100} \times 1.5 \times \frac{1}{60} = 1,150 \text{ scfm}$$

(3) Heat requirements:

Water = 2,000 lb/hr x .846 x 1700 Btu/lb	=	2,870,000 Btu/hr
Fluid air = 1150 scfm x .02 x 1330 x 60	=	1,840,000 Btu/hr
Totals (except loss to walls)		4,710,000 Btu/hr

(4) Methane needed (assume 20% heat input loss to walls)

$$0.8\,[V_{CH_4} \times 1000 \text{ Btu/cf} + 4,620,000] = 4,710,000 + .02 \times 1330 \times 10V_{CH_4}$$

$$V_{CH_4} = \frac{1,014,000}{534} \times \frac{1}{60} = 31.7 \text{ scfm}$$

(4) Fluid bed diameter:

$$A = (1150 + 317) \times \frac{1400 + 460}{530} + 2.0 \times 60 = 43 \text{ ft}^2$$

$$D = 7.4 \text{ ft}$$

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Fluidized-bed Incineration of Selected Carbonaceous Industrial Wastes

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27 Abstract

This report describes a program that was conducted on the feasibility of fluidized-bed incineration for selected carbonaceous industrial wastes. The program consisted of an initial phase in which wastes from the paint, plastics, rubber, and textile industries in Ohio were characterized. In the second phase, samples of various wastes were obtained and analyzed, and based on their characteristics, selected wastes were experimentally incinerated in a 10-inch-diameter fluidized-bed system.

Results of the program indicate that sludges from solvent recovery operations in the paint industry, sludges from primary treatment of process wastes from plastic manufacturing, flotation sludges from primary treatment of synthetic rubber manufacture, and the waste from the viscose process of the textile industry can be incinerated in a fluidized-bed system without the production of noxious or toxic exhaust gases. The program also indicates that incineration of the various wastes significantly reduces their potential impact on stream pollution. It is recommended that a demonstration plant be constructed and operated at a site close to the source of several types of industrial wastes.

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